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The Corsi Block-Tapping Task: Methodological and Theoretical Considerations

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The Corsi block-tapping task has enjoyed extensive use in clinical and experimental studies for a quarter of a century and is arguably the single most important nonverbal task in neuropsychological research. Nevertheless, there has been considerable inconsistency not only in the administration and scoring of this measure, but also in the physical properties of the test apparatus. In this paper, we survey a wide range of studies that have made use of the block-tapping task during the past 25 years and provide a detailed appraisal of the manifold methodological variations. Additionally, we discuss the historical context in which the Corsi originated and offer a critical examination of the cognitive processing operations purported to underlie performance on this task. © 1998 Academic Press

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The Corsi block-tapping task (Corsi, 1972) is a simple yet powerful test that has been employed by clinical neuropsychologists as well as developmental and cognitive psychologists. Its use has been international in scope, with particular interest in Italy, Great Britain, and the United States. The age range to which it has been applied extends from preschoolers to octogenarians. Clinical populations studied to date have included learning-disabled children, the mentally retarded (among them, Down syndrome and Williams syndrome), Korsakoff's patients, demented individuals (e.g., with Alzheimer's and Huntington's disease), and a myriad of other neurological disorders. The Corsi task has become prominent enough to be included as a component of a major neuropsychological battery (Kaplan, Fein, Morris, & Delis,

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1991) and has recently been adapted to a number of computerized formats (e.g., Morris et al., 1988; Smyth & Scholey, 1994). It has been used for a variety of purposes, including the assessment of deficits in immediate nonverbal memory (De Renzi, Faglioni, & Previdi, 1977; De Renzi & Nichelli, 1975; Morris et al., 1988), investigating developmental changes and gender differences in spatial skills (Capitani, Laiacona, & Ciceri, 1991; Isaacs & Vargha-Khadem, 1989; Orsini et al., 1986), and more recently, for clarifying theoretical conceptions of visuospatial memory (Jones, Farrand, Stuart, & Morris, 1995).

Given the wide-ranging use of this task over the past quarter century, it is unfortunate that there exists little in the way of traditional indices of standardization. That is, a paucity of reliability data have been reported, and variations in almost every task parameter have been employed, among them block arrangement and scoring method. Additionally, important procedural details are frequently not reported. Nonetheless, the task continues to be employed not only for clinical purposes but also more recently for use in experimental investigations of spatial information processing. Consequently, it seems fitting that a quarter of a century after this task was introduced, a critical appraisal of its methodological aspects and theoretical implications be undertaken.

To this end, we begin by presenting an account of the origin of the Corsi task. Next, we describe the conceptual and historical frameworks which support the notion that it continues to be a viable and important method for investigating discrete information processing abilities. We also examine procedural aspects of the Corsi as regards its utility in clinical and experimental contexts, providing an assessment of major features such as display format, length of block sequences, discontinuance criteria, and scoring technique. Rather than focusing on the findings of studies, this review is aimed at delineating the range and frequency of use of the major task parameters. Following this, we discuss various theoretical conceptions of the mechanisms presumed to underlie performance on this task. Finally, we make specific suggestions for further research.

ORIGIN OF THE CORSI TASK

As shown in Fig. 1, the original Corsi apparatus consisted of a series of nine blocks arranged irregularly on a 23 × 28 cm board (9 × 11 in. as reported in Milner, 1971). The blocks are tapped by an examiner in randomized sequences of increasing length.

Immediately after each tapped sequence, the subject attempts to reproduce it, progressing until no longer accurate. The task was developed initially as a nonverbal analogue to the Hebb recurring digits paradigm (Hebb, 1961) in order to assess incidental learning in epilepsy patients following temporal lobe excision (Corsi, 1972; Milner, 1971). This work was carried out at

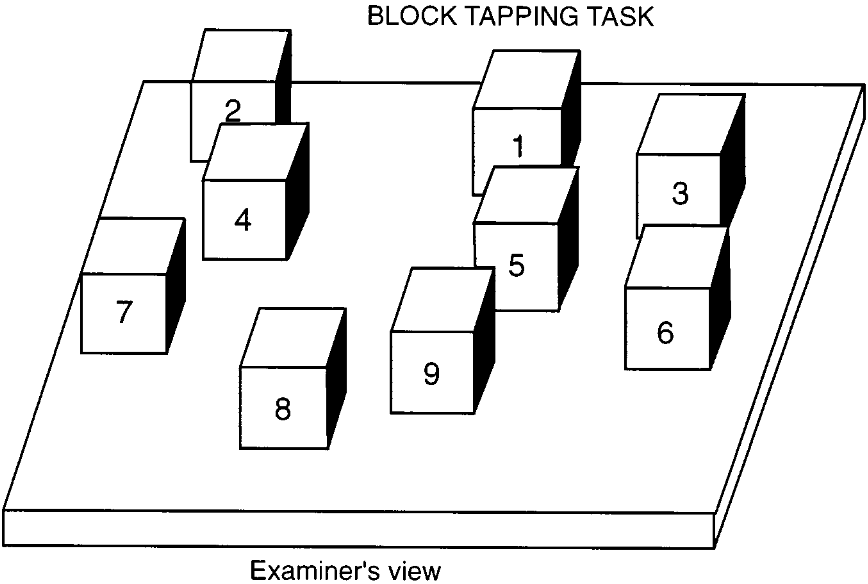

FIG. 1. The original illustration of the Corsi apparatus (reprinted from Corsi's doctoral dissertation, 1972).

McGill University's Montreal Neurological Institute and was prominent among the early research examining lateralized, material-specific cognitive processing. These investigations of patients with temporal lobe excisions demonstrated the importance of mesial structures for memory and provided evidence regarding lateralized mediation of verbal and spatial memory processes (Milner, 1978). Additionally, these studies were among the seminal works that led to a greater appreciation for right hemisphere function (Milner, 1974).

The original Corsi studies (Corsi, 1972; Milner, 1971) showed a double dissociation between auditory digit sequences and visual block-tapping sequences in left and right unilateral resection groups. The degree of preservation of secondary memory ability was related to the extent of temporal lobe excision, specifically the degree of loss of medial temporal lobe tissue (Corsi, 1972). Based on these findings, it was inferred that the left medial temporal lobe mediated memory consolidation of verbal (spoken digit) sequences, while the right medial temporal region mediated memory consolidation of spatial (block-tapping) sequences (Milner, 1978). The initial findings were so persuasive, both with respect to the demonstration of focal mediation of material-specific function and in terms of a dramatic double dissociation, that *with no further validation*, they firmly established the Corsi procedure as one of the preeminent measures of spatial memory. However, as we discuss later in this paper, the cognitive processing functions underlying performance on the Corsi task are by no means clearly understood. Several questions can be raised concerning such mechanisms. For example, does the sequential nature of the Corsi procedure inadvertently complicate the interpretation of it as a pure measure of *visuospatial* or configural processing? Moreover, even if visuospatial processing is in fact the prepotent factor contributing to variations in performance, is the underlying mental operation best characterized as a type of *visual* imagery or as some sort of amodal, spatial attention mechanism?

HISTORICAL CONTEXT

Today, the study of spatial processing is accorded much greater significance than before the 1970s. However, a variety of influences that developed simultaneously, yet independently, began to yield increased recognition of the importance of nonverbal information processing. The subdisciplines most affected by this growing awareness were neuropsychology, cognitive psychology, intelligence, gender differences, and cognitive development.

Within neuropsychology, one of the major influences was the emerging realization that the right hemisphere did in fact play an important role in nonlinguistic thinking, specifically in the processing of spatial information. Indeed, during the initial stages of the contemporary period in cognitive neuroscience, Milner (1974) coined the term ''hemispheric specialization'' to replace the term ''hemispheric dominance.'' The latter had referred to the superiority of the left hemisphere in language processing and implied a relative disregard for spatial processes. The conceptual shift occurred as a result of work with clinical samples demonstrating left-sided mediation of language, but more importantly, the asymmetrical mediation of verbal and nonverbal memory function. Around the same time, the work with split-brain patients came into prominence and firmly established the notion of differential specialization of the two hemispheres (Gazzaniga, 1970).

A major advance within the field of cognitive psychology in the early 1970s yielded the strongest empirical evidence to date supporting the hypothesis that mental imagery is a viable representational medium. Specifically, by plotting reaction time functions for making same-different judgments concerning pictures of three-dimensional shapes in varying angular orientations, Shepard and Metzler (1971) confirmed that subjects employed a mental rotation process analogous to that of physical rotation in space. It is interesting to note that this paper, arguably one of the single most highly cited articles in the psychological literature, appeared in the same year as Milner's (1971) classic paper reporting the use of the Corsi task. Nevertheless, little connection between the processes of spatial imagery and the Corsi task was made over the intervening years.

The growing interest in the study of gender differences in cognition following the classic work of Maccoby and Jacklin (1974) led to numerous studies of such differences using a variety of putatively spatial tasks. Although several studies have been carried out concerning gender differences on the Corsi task in which massive numbers of subjects have been examined (e.g., Capitani et al., 1991; Grossi, Orsini, Monetti, & De Michele, 1979; Orsini et al., 1986), this work has had little if any influence on the continuing debate concerning the reliability, validity, and magnitude of gender differences on spatial tasks (Halpern, 1992; Voyer, Voyer, & Bryden, 1995). This is perhaps due in large part to the fact that such research has been published almost exclusively in journals that are not typically surveyed by investigators who have reviewed the relevant literature.

Another example of the independently evolving importance of spatial processing can be found in the theoretical conceptions of Gardner (1983), who elevated this ability to a kind of intelligence unique from that of linguistic, logical-mathematical, and musical, among others. Additionally, the flourishing of the information-processing approach to the study of intelligence during this same period led to extensive development and testing of detailed, algorithmic-type models of performance on chronometric versions of psychometric spatial tests (Pellegrino & Kail, 1982).

As a final example, within the domain of developmental psychology, the study of spatial processing gained prominence from the late 1960s through the 1980s. Relevant topics included the examination of Piaget's concept of egocentrism or spatial perspective-taking in preschoolers (Newcombe, 1989; Piaget & Inhelder, 1967), developmental changes in the use of cognitive maps for representing large-scale space (Cohen, 1985), and children's spatial short-term memory (Berch, 1979).

In sum, a series of rather independent advances were achieved in the study of spatial processing during the past quarter century, representing approaches and interpretations from several different subdisciplines of psychology. It should be pointed out, however, that several attempts were made to integrate these disparate lines of research during the 1980s, primarily by publishing edited books comprised of literature reviews authored by distinguished researchers from different subdisciplines. Nonetheless, these reviewers typically neglected to make any mention of the Corsi task (e.g., Potegal, 1982).

History will no doubt repeat itself in this regard if the potential importance of the Corsi task and the need for more rigorous study of the cognitive processing operations underlying performance on it are not brought to the attention of contemporary researchers. Apropos of this, the objective of the remainder of this paper is to provide a detailed, methodological review and theoretical analysis of the Corsi task. The time is clearly ripe for such an examination, given the recent re-emergence of spatial processing as an important focus of interest in the field of neuropsychology in particular and the area of cognitive neuroscience in general. Consistent with this perspective, Jones, Farrand, Stuart, and Morris (1995) have recently noted that within the realm of visuospatial memory, the study of serial order has been the exception rather than the rule. Fortunately, the Corsi task is uniquely qualified for the assessment of serial spatial memory.[1]

METHODOLOGICAL CONSIDERATIONS

A thorough but not exhaustive search was conducted to examine variations in the task parameters reported by investigators who have made use of the Corsi task. Key word searches were conducted in Psychlit (1974–1996) and in Medline using the terms ''block span,'' ''block tapping test,'' ''Corsi,'' ''Corsi blocks,'' ''memory and blocks,'' ''spatial span,'' and ''visual span.'' Additional articles were identified through the reference citations published in accessible papers. Articles were excluded if they were not published in English or did not specify the parameters and administration instructions. This approach yielded a total of 38 papers (see the Appendix for a list of these references). As our review will show, the many variations and modifications of numerous task parameters, most of which have been developed with no explicit rationale, prohibit any kind of systematic compilation and evaluation of the data emanating from these studies (e.g., through the use of meta-analytic procedures). Concomitantly, this state of affairs has precluded any careful assessment of conventional psychometric properties of the Corsi task in the form of reliability and validity coefficients. More will be said later about the need for standardization in the context of clinical utility, and alternatively, about the practice of manipulating task parameters as a means of evaluating theory.

In reviewing the task parameters of the 38 empirical studies, we classified these features into four major categories: display characteristics, administration, recall order, and scoring techniques. The rationale for this classification scheme was straightforward and emanated from routine measurement practices. First, ''display characteristics'' includes the predominant features of any visuospatial task. Second, the procedural features of most assessment techniques are commonly described under the rubric of ''administration.''

[1] Knox (1914) developed a block-tapping task that has subsequently become known as the Knox Cubes Imitation Test. It was originally devised as part of a series of performance tests for assessing intellectual deficits in immigrants at Ellis Island. Pintner (1915), who subsequently standardized the test, described the apparatus as consisting of four blocks affixed to a base and spaced about 2 in. apart. Using a fifth block, the examiner taps the blocks in a prearranged order at a rate of about one per second. The subject then attempts to repeat the sequence using the same fifth block. For a reason not specified, all of the 12 sequences begin with the far left cube. On the first trial, the examiner taps the blocks in a left-to-right order. Eight of the remaining 11 trials are comprised of different random orders that include the tapping of one or two blocks more than once. (The interested reader should consult Berch (1979) for a discussion of Pintner's (1915) findings.) It should be noted that with the exception of being included as a subtest in several intelligence scales (e.g., The Arthur Point Scale of Performance, 1947) there has been a dearth of either clinical or neuropsychological research making use of this test.

Third, ‘‘recall order’’ constitutes a major defining property of any task requiring sequential memory. Fourth, ‘‘scoring techniques’’ are fundamental to evaluating performance on psychological measures.

Display Characteristics

Display characteristics included the color, number, and size of the blocks, block placement, and the area taken up by the display. Fifty percent of studies used nine black blocks, affixed on a black, 20 × 25 cm baseboard in the original Corsi/Milner positions. However, there have been numerous variations in each of these parameters.

Color. At least four studies used white blocks on a white board, one used blue blocks on a yellow board, and another, white squares on a computer screen that turned black when touched in the correct sequence.

Number. While virtually every study we examined used nine blocks, it is interesting to note that the WAIS-R Neuropsychological Inventory (Kaplan et al., 1991) uses 10 blocks, with five blocks on each half of the board so as to permit an assessment of visual field neglect.

Block size. Unquestionably, the greatest variation in the display was the size of the blocks. The original blocks were 3 cm cubes. Although ten studies reported using blocks of this size, six others employed smaller blocks (2.5 cm cubes) while another six used larger blocks (4.4 cm or 4.5 cm cubes).

Block placement. None of the investigators, including Corsi (1972) himself, reported specific distances between the blocks, and the majority did not even provide an illustration of the block placements they used. Those that did depict the block arrangements or mentioned anything at all about this feature apparently used sets of blocks in which the placements varied only marginally from those originally used by Corsi (first illustrated in Fig. 3 from the article by Milner, 1971). This is shown in Fig. 2a from an aerial perspective (and from the vantage point of the examiner). However, several researchers have incorporated more extreme variations in block placement per se. For example, as shown in Fig. 2b, the relative locations of the blocks are very different as compared with the standard. Note also that the numbering of the blocks is quite different from the standard, that is, in terms of both the general locations of the blocks themselves (e.g., 8 is at the lower left in Fig. 2a and the upper right in Fig. 2b) and the distances between certain pairs of numbered blocks (e.g., 1 and 3). In Fig. 2c, the numbering of the blocks also differs from that of the standard, but the original placements are only marginally different. Fig. 2d shows an arrangement that differs from the standard in three ways: 10 blocks rather than 9, different block placements, and different numbering. It should be pointed out that differences in either or both of the latter parameters can yield marked differences in path configurations when the same Wechsler digit span sequences are employed. As noted below (see section on Block-Tapping Sequences), it has been dem-

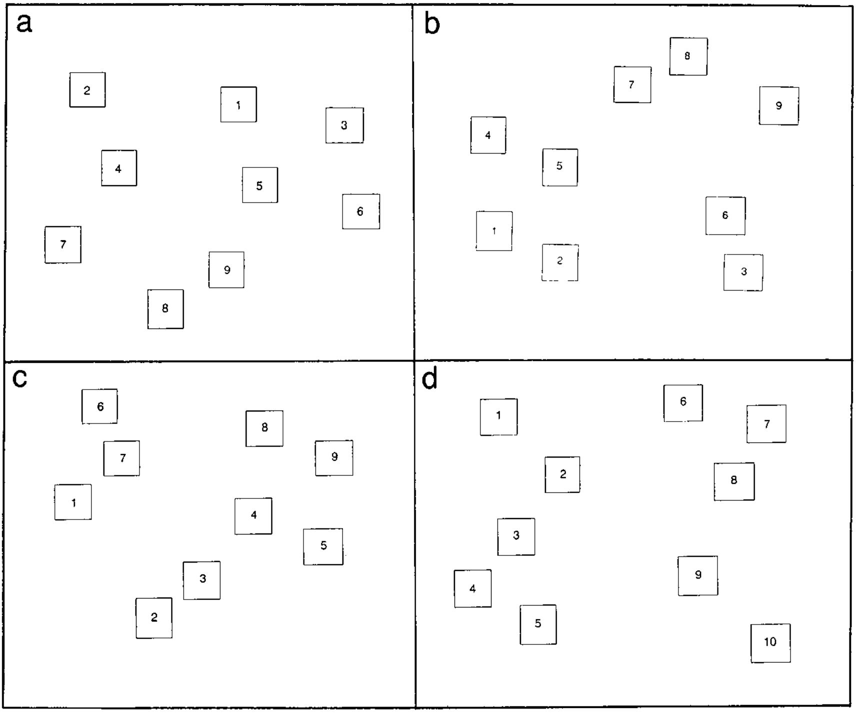

FIG. 2. Illustrations of four variants of block placements in the Corsi task as viewed from an aerial perspective and from the vantage point of the examiner: (a) the standard display, (b) the display used by De Renzi and Nichelli (1975), (c) the display used by De Renzi, Faglioni, and Previdi (1977) and (d) the display used in the WAIS-R NI battery (Kaplan et al., 1991).

onstrated that complexity of the path configuration can influence performance independent of the length of the sequence (Smirni, Villardita, & Zappala, 1983). Finally, it should be pointed out that with the advent of computerized, two-dimensional Corsi displays that are rapidly becoming available in neuropsychological software batteries (e.g., Davis, Bajszar, & Squire, 1993), the examiner can generate multiple variants of randomly placed blocks by the touch of a key.

Display area. With respect to the area taken up by the display, most studies failed to report this information. Of those that did, the majority used the 20 × 25 cm baseboard that could be considered the standard. Nevertheless, some variations have been reported, including a 22 × 28 cm board and a 26 × 31 cm board. Parenthetically, whereas Corsi (1972) referred to a 22 × 28 cm board (9 × 11 in.) when describing the original apparatus in his dissertation, Milner (1971, 1978), reporting on the same data, indicated that the board size was 20 × 25 cm (8 × 10 in.).

At first glance, one might judge variations in the size and shape of the baseboard to be of trivial concern. However, these features should not be disregarded, as alterations in them can produce corresponding changes in block distance and block placement. Smaller distances among the blocks could influence the ease of mentally representing sections of the display, and variations in block placement could differentially affect the complexity of the path configurations generated by the block-tapping sequences. Furthermore, display features become particularly important in computerized versions of the Corsi task, because not only is the spatial array altered (relative to the three-dimensional model), but the overall size and shape of the display are as well. In other words, performance may be affected by a reduction in display size (due to the use of comparatively small computer screens) and/or by alteration of the block positions, thereby changing the path configurations (as discussed below).

Test Administration

Administration features included the manner in which the examiner points to the blocks, the block-tapping rate, the starting point, the number of trials per level, the discontinuance criterion, and the configural disposition of the paths determined by the block sequences.

Pointing procedure. Few investigators reported the manner in which the blocks were pointed to by the examiner. Informal discussion with several of our colleagues who have used the Corsi task in clinical settings revealed that some use the index finger to tap the blocks and lift the hand straight up before moving it to the next block, some use the index finger but move it from one block to the next without lifting the hand, and still others have used a pencil or a stick to tap the blocks, the method employed in Corsi's (1972) initial experiments.

Block-tapping rate. Twenty of the studies reviewed failed to mention the rate at which tapping sequences were presented. Of the 18 studies that did specify tapping rate, 11 examiners chose to tap blocks at the rate of one block per sec. Others tapped them at the rate of one block every 1.5 s or one block every 3 s.

Starting point. While the starting level for the task began with two-block sequences in 18 of the studies reviewed, others began with one-block (four studies), three-block (three studies), or four-block (two studies) sequences.

Trials per level. The studies also differed in the number of trials administered to subjects at each level. In a majority of them, subjects received 2 trials per level. However, there was a great deal of variation among the studies. One examiner administered only 1 trial per level, while eight presented 3 trials per level, and seven gave 5 trials per level. In addition, one study employed a ''10 at most'' criterion where subjects received a maximum of 10 trials per level.

Discontinuance criterion. The criterion by which test administration was terminated differed across studies. For studies that employed 2 trials per level, subjects repeated increasingly longer block sequences until they missed both trials at a particular level. Examiners who administered a maximum of 5 trials per level stopped subjects when they failed to correctly repeat three of the 5 trials at a given level. The 10-trials-per-level criterion included discontinuance when subjects were unable to correctly repeat a single sequence out of the first 6 trials they received.

Block-tapping sequences. The majority of studies did not specify the procedure used to generate the block-tapping sequences. Of those that did, two employed tapping sequences drawn from the *Wechsler Memory Scale—Revised,* and a few studies used the sequences developed by Smirni, Villardita, and Zappala (1983). Several used the digit sequences from the Digit Span subtest of the Wechsler intelligence scales (i.e., the WISC-R [Wechsler, 1974] or the WAIS-R [Wechsler, 1981]). In the latter studies, the digits were assigned to the blocks as a means of determining which blocks would be tapped as well as the order in which this would occur. This method might appear to provide a correspondence between any given sequence of spoken digits and its purported block-sequence counterpart, thus implying a parallelism or equivalence between the procedures, especially in studies where the digit span test is administered as well. However, the fact that there may be substantial dissimilarities in mentally representing orally presented digit sequences as compared with visually presented block-tapping sequences would suggest that the putative item-for-item equivalence is erroneous.

Additionally, it is generally assumed that longer digit and block-tapping sequences are more difficult for patients and subjects to reproduce because of the greater immediate memory load. There is considerable indirect evidence from developmental studies corroborating this general effect for length, in that scores increase with chronological age, and presumably, with increasing cognitive capacity (Grossi et al., 1979; Kaplan et al., 1991). However, there are also data showing that different block-tapping paths of equal length elicit differences in performance, suggesting that path configuration (i.e., the shapes formed by the hypothetical lines connecting the blocks in any given sequence) is an important factor in this task, independent of path length per se (Smirni et al., 1983). In the Smirni et al. study, 58% of subjects who failed on shorter paths subsequently succeeded on longer paths. However, after statistically controlling for differential path difficulty (as measured by mean performances), only 6% of subjects succeeded on trials with longer paths after having failed a trial with a shorter path. In addition to demonstrating the potency of path configuration, these data also suggest that what appears to be inconsistent performance for any given subject may reflect more accurately the differential difficulty of paths of equal length.

Recall Order

Recall order is concerned with whether the block-tapping sequences must be reproduced in forward or backward order. When using the Corsi for the study of immediate memory, the examiner may require recall of either or both of these. Of the 38 studies reviewed, all assessed forward recall, but only three assessed backward as well as forward. One of the three did not report any comparison between these two procedures (Daum et al., 1993), a second, a developmental study with normal children, found no difference between forward and backward recall (Isaacs & Vargha-Khadem, 1989) and a third study replicated the latter result (Berch & Foley, 1998).

It is interesting to compare this outcome to the well-substantiated finding that performance on forward recall with digits is typically better than on backward recall (e.g., Gardner, 1981). Perhaps the best explanation of this result is that having to recall digits in backward order demands a greater working memory load than does forward recall, requiring some kind of transformation of the input (Case, 1978). In contrast, given that path configuration appears to be a prepotent factor in the forward Corsi task, it would seem reasonable to expect that having to recall the locations along a path in backward order might not be any more difficult than recalling the same locations in forward order. That is, the examinee may be able to simply ''read off'' the sequence from a covert visuospatial representation. Although this conjecture remains to be validated, it nonetheless could turn out to be of crucial importance in future comparisons of the similarities and differences between the cognitive processing mechanisms underlying performance in verbal and spatial span tasks. This is especially true, given a recent review of neuropsychological evidence along with some compelling experimental data on college students (Li & Lewandowsky, 1995) that provides strong support for the hypothesis that even backward recall in verbal span tasks may rely on visuospatial representations (Weinberg, Diller, Gerstman, & Schulman, 1972).

Finally, it should be pointed out that the third study we reviewed here did, in fact, reports that forward recall with the Corsi was somewhat higher than backward recall (Helmstaedter et al., 1996). However, as this study was carried out with epilepsy patients (the finding was obtained for both frontal lobe and temporal lobe subgroups), it is unclear to what extent lateralized cerebral lesions may have been responsible for this outcome. At the very least, it is obvious that additional data are needed to resolve this issue.

Scoring

The variations in scoring techniques included percentage correct, percentage correct by position, the span limit, use of partial credit, and combining of forward and backward span scores. In his initial study, Corsi (1972) reported group mean percent scores based on the percent correct for each subject. This score was derived from the number of sequences reproduced correctly divided by the total number of sequences to be learned. In all the other studies that examined recurring sequences, mean percent correct also was used as the outcome measure, with only one of these awarding partial credit. The great majority of studies investigated immediate memory and used span length as the outcome measure. Span length or span limit represents a capacity measure and refers to the level above which the subject is unsuccessful in reproducing block-tapping sequences. In this sense, level is defined by the number of items in the block-tapping sequence. One or more different sequences may be presented at a certain level. However, as noted earlier, the criteria that determine when the span limit has been reached varied across studies. Finally, partial credit was granted in only 2 of the 38 studies.

Despite the number of variations in task parameters described above, comparatively little effort has been devoted to examining the contribution of such factors to variations in performance. No doubt it is likely that some of these would be anticipated to have almost no effect while others may prove to be of critical importance. Although there are no data, one might presume that task components that have little to do with the fundamental spatial and working memory demands of the procedure would not influence performance in a meaningful way. One could argue that the color and size of the blocks would be examples of factors that are not relevant to such task demands. In contrast, both the number and placement of the blocks might be expected to yield variations in performance levels. The greater the number of blocks, the greater the likelihood of not recalling exactly which blocks were tapped. And as already discussed, different block placements could affect the path configurations generated by the same numbered sequence. As regards administration of the Corsi task, one would not anticipate that the manner of pointing to the blocks would make all that much of a difference. However, block-tapping rate, starting point, and number of trials per level certainly might, as could the discontinuance criterion. It remains to be seen how tapping rate would affect scores, but it is likely that up to some optimal level, the faster the tapping rate the easier it might be to recall any given sequence, especially for longer sequences. Start points in the center region of the display might well be harder to recall than those near the periphery. With respect to the number of trials per level, the greater this number, the poorer may be the overall level of performance, because proactive interference may build up during the session. Finally, the type of scoring technique used would affect performance levels in obvious ways.

Two task parameters that have been investigated to some extent are direction of recall and path configuration. With respect to the former, as noted above, the evidence thus far suggests that there is generally no difference between forward and backward recall. This result may reflect the importance of path configurations in the Corsi task. Block-tapping paths that differ in configuration but are equal in length can in fact yield performance differences (Smirni et al., 1983). That is, to the extent that the hypothetical lines connecting the blocks in a given sequence serve as the primary basis for reproducing that sequence, forward and backward recall should lead to little if any difference. For example, if the path formed by a sequence of three blocks is triangular in shape, then one should reproduce that shape equally well going in either a forward or backward direction, assuming that one could recall the first or last block to be touched, respectively. Furthermore, the processing demands needed both for encoding any given configuration and storing it temporarily in working memory may be substantially greater than those associated with retaining sequential information.

THEORETICAL CONSIDERATIONS

What information processing operations does the Corsi task measure? The answer is by no means straightforward, and for the most part, the evidence does not come from the domain in which this task has seen its greatest use: clinical neuropsychology. The main reason for this is that although the demonstration of various kinds of dissociations between spatial and verbal tasks for groups of subjects differing in loci of brain lesions can be indicative of modular functioning, both parameter manipulations and functional cognitive theorizing are needed in order to complete the picture. While these types of approaches are the *sina qua non* of cognitive experimental psychology, as noted earlier, developments in the study of mental imagery did not influence research on the Corsi task, despite almost simultaneous emergence in the early 1970s. Concomitantly, although the seminal paper by Baddeley and Hitch (1974) appeared soon afterward, in which specialized modules for processing verbal and visuospatial information were postulated to be part of a larger working memory system, it was not until the 1980s that these theorists began exploring this distinction in earnest (Baddeley & Lieberman, 1980).

Most recently, this line of work has culminated in an extensive corpus of studies, exemplified by the use of dual-task approaches for examining the factors that interfere with information in visuospatial immediate memory. In studies by Smyth and her colleagues, both the traditional Corsi block span test and a computerized version have been used (Smyth & Scholey, 1992, 1994). Based on their most recent series of experiments, they argue that the maintenance of spatial items in serial order within immediate memory requires active spatial attention. They interpret their findings as indicating that any secondary task that makes demands on spatial attention will interfere with performance on the Corsi block span task, whether that secondary task is visual, auditory, perceptual, or motor in nature. This work emanates in part from the findings and theoretical views of Farah, Hammond, Levine, and Calvanio (1988), who first provided evidence for a dissociation between visual imagery (the representation of color and form in the visual sensory modality) and spatial imagery (a more abstract representation of the relationships between objects in space).

However, even more recently, the view that spatial and verbal short-term memory are independent has been seriously challenged. Specifically, Jones et al. (1995) have argued that the mental representations of verbal and spatial information in serial short-term memory are functionally equivalent. The key component that led to this unitary model is that of ‘‘changing state,’’ in which a stream of information is shifting, as opposed to being repetitive. For example, in the classic irrelevant speech paradigm, serial verbal recall is disrupted by the presence of background speech or consonants, such as ‘‘dah,’’ ‘‘dah,’’ ‘‘dah.’’ However, the effect is much stronger when consonant sounds change, such as ‘‘dah,’’ ‘‘gah,’’ ‘‘bah.’’ Essentially then, these investigators posit that interference with performance on a serial spatial task by a secondary task is primarily attributable to the extent to which the latter meets the conditions of changing state, irrespective of the modality (auditory, visual, tactile) of this interfering task. In a series of experiments, Jones et al. (1995) demonstrated analogous effects in serial spatial memory, regardless of whether the interfering task was spatial (rote tapping) or verbal (either mouthed utterances or irrelevant speech).

Undoubtedly, the aspect of the primary spatial task that was critical to this demonstration was elimination of the need to remember the locations of the spatial ‘‘items.’’ These investigators point out that in the standard Corsi task, subjects must retain not only the sequential information, but also the location of the blocks that have been tapped. They contend that if a researcher’s primary interest is in subjects’ serial processing per se, then requiring them to remember block location can confound the results. Consequently, they devised a serial spatial span task in which dot sequences (varying in length) were presented on a computer screen, followed immediately by a blank screen, and then all the dots were represented simultaneously. Subjects had to designate the *order* in which the dots had originally appeared by pointing and clicking with a mouse (with the shading of each dot changing after being chosen). Additionally, the spatial locations of the dots varied from trial to trial. Finally, Jones et al. (1995) examined serial position effects; that is, they plotted accuracy as a function of the temporal position (first, second, third . . . last) of any given dot. Analysis of these curves revealed the existence of recency effects for serial spatial memory greater than for the last item alone, which were comparable to those achieved for serial verbal memory.

Taken together, these most recent findings appear to call into question the view that spatial and verbal memory performance are reflective of functionally, and perhaps neuroanatomically different systems. Of course, this conclusion is at odds with a wealth of other data emanating from cognitive, neuropsychological, and more recently, neuroimaging studies (see Jonides et al., 1996, for an excellent review), as well as the corpus of evidence that has accrued through the use of the Corsi task with brain-damaged populations. Finally, the results of Jones et al. (1995) were derived from a task in which critical spatial aspects of the Corsi task were minimized in order to evaluate the serial order components per se. Nevertheless, the theoretical and methodological perspective proffered by Jones et al. (1995) provides an important foundation for future research efforts aimed at clarifying the mental operations underlying performance on the standard Corsi task as well as on more recent variations of this measure. Indeed, perhaps the most important contribution of their work for the present review is the implication that the standard Corsi task may be inherently deficient for assessing retention of the serial order of spatial locations. That is, as Jones et al. point out, in the standard version, the recall of item information (spatial locations) is confounded with the retention of order information (see Krikorian, Bartok, & Gay, 1996 for a similar argument). Although this is a noteworthy point, as discussed earlier, the findings of Smirni et al. (1983) suggest that path configurations rather than separate block locations actually constitute the critical item information. In other words, what Jones et al. (1995) considered to be the confounding factor in the Corsi task, that is, the spatial location information, may turn out to be one of the most important functional components in the standard Corsi task. To the extent that this holds up, the role of serial order processing in reproducing the sequences in the standard Corsi procedure may prove to be of much less significance than has heretofore been assumed.

Corsi (1972) developed the block-tapping task as a spatial alternative to procedures assessing memory for verbal sequences, as represented by the digit span task. However, the question remains as to whether the original data with left and right temporal excision groups indicated a material-specific effect for a single underlying process of memory for sequences or whether other fundamental processes, perhaps specific to sensory modality and/or to the nature of the task (sequential or configural) are involved.

SUGGESTIONS FOR FUTURE RESEARCH

The question of primary importance concerning the Corsi task was posed at the beginning of the previous section, namely, ‘‘What information processing operations does the Corsi task measure?’’ Perhaps the most significant, yet widely unappreciated study to date that goes a long way toward answering this question is that of Smirni et al. (1983), regarding the potentially crucial role of path configurations. Do subjects reproduce block sequences by constructing mental path configurations from the patterns generated by the examiner’s tapping sequences? If so, are there individual differences in the ease with which subjects can use such a strategy successfully, and could these be linked to factors such as the ability to construct a high-quality mental image or the ability to hold such an image in working memory? At the very least, the findings of Smirni et al. need to be replicated. Beyond this fundamental demonstration, however, there is a great need to explore the basic components of configural processing in the Corsi task as well as to extend this work in ways that not only may help explain previous findings but also clarify some of the theoretical issues discussed above.

Additional suggestions for future research, described in more detail below, include: (1) carrying out standardization studies of the basic Corsi procedure in order to generate normative data and indices of reliability and validity; (2) conducting experimental studies involving the manipulation of potentially critical task parameters such as path configuration as influenced by block placement and block-tapping sequences; (3) comparing performance on two-dimensional computerized versions of the Corsi to performance on the standard, three-dimensional version; and finally (4) documenting the details of the display, procedural steps, and the scoring technique of any given study.

Standardization vs. Manipulation of Task Parameters

Although the classic Corsi has proven extremely useful for both clinical and experimental purposes since its inception, we believe that its future utility will be severely constrained by not only the lack of requisite data concerning its psychometric properties, but also by limitations inherent in the use of the three-dimensional apparatus per se. Certainly, the availability of a standard apparatus provided by the WAIS-R Neuropsychological Inventory will increase not only the consistency of the physical, administrative, and scoring parameters of the task, but will also yield normative data as well as the reliability and validity coefficients needed to achieve the status of a truly standardized instrument. However, from a theoretical standpoint, the varying of relevant task parameters is precisely what will be required for continued progress in delineating the cognitive processing operations underlying performance on this task. In other words, the fixed, standardized administrative and stimulus-related properties that are the hallmark of a psychometric, individual-differences approach appears to be at odds with the flexibility in being able to vary these same parameters that constitutes the *sina qua non* of a nomothetic, experimental approach (Cronbach, 1957).

Certainly, attempts at forging a rapprochement between these seemingly conflicting research strategies have achieved some success over the past 20 years in the field of intelligence, following the seminal efforts of Sternberg (1977). That is, by manipulating potentially critical features of the standard Corsi task based on theoretical conceptions derived in part from the kind of task analysis provided in the present paper, studies can be carried out that are likely to enhance our understanding of the critical cognitive processing operations. However, what has been missing from any such attempts to date are comparisons between performance on the experimental versions and the standard task itself.

Computerized Versions of the Corsi Task

In order to successfully conduct detailed studies involving the careful manipulation of critical task parameters, the use of a computerized version of the Corsi task is especially important, given the increasing likelihood that such versions will eventually lead to the replacement of the original apparatus even in clinical situations. As such, we conclude by offering several suggestions as to the advantages of such an approach. First, to date, computerized versions of the procedure have already been developed and used in several studies (Jones et al., 1995; Joyce & Robbins, 1991; Lange et al., 1992; Morris et al., 1988; Owen, Downes, Sahakian, Polkey & Robbins, 1990; Robbins et al., 1992; Smyth & Scholey, 1992). The most obvious way in which these vary from the standard task is that two-dimensional stimuli are used rather than the traditional three-dimensional blocks in the wooden model. Additionally, the stimuli are presented in a vertical orientation (although this would not have to be the case), and the path sequences are typically designated by color or brightness changes rather than manual pointing to the blocks.

The potential advantages of a computerized version include the following: (1) automatic scoring which can ensure greater accuracy than manual scoring and allow for the recording of latencies between taps as well as the overall duration of the response; (2) freedom from manual stimulus presentation and scoring which might allow the examiner to observe other characteristics of the subject's behavior that may aid in interpreting performance (e.g., distractibility or physical movements during stimulus presentation that may be indicative of motoric encoding or rehearsal); (3) the number of blocks, size of blocks, and block placement can easily be varied for experimental purposes and for within-subject manipulations of factors that could affect difficulty independent of block sequence length; (4) distractors can be added during a delay interval or at other times; and (5) other variants of the task can be devised (e.g., Jones et al., 1995, where lighted blocks appeared successively and no other block was displayed until the response began).

Despite the advantages of a computerized version of the Corsi task over the original three-dimensional manual apparatus, comparative studies should be carried out to ensure that any performance differences are not reflective of potentially important differences in the underlying cognitive processes of interest.

Documentation of Procedures

Perhaps our most important suggestion for investigators who wish to make use of the Corsi task, whether for theoretical or clinical purposes, is that they carefully describe the details of their apparatus and procedure, thereby permitting not only the replicability of their work but also increasing the ease and accuracy with which subsequent reviews can summarize the relevant literature.

APPENDIX

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