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ABSTRACT

As part of an experimental research program on lifespan naturalistic and laboratory memory for spatial representation, investigators examined interactions between the effects of visual and kinesthetic encoding and age on memory for space using a modification of the Sinnott (1987) human maze paradigm. It was hypothesized that an age effect favoring younger subjects would be present such that younger participants would perform better overall on the maze task, that older subjects would perform better on a Styrofoam mock-up of the maze-like floor plan compared with a paper version, and that the addition of kinesthetic information would prove especially helpful to older participants. Eighty-three older (mean age of 68.29) and 83 younger (mean age of 20.89) urban respondents were asked to remember a route through a building after being presented with one of four conditions giving either realistic or paper and pencil spatial information. The second two hypotheses were not supported; however, analysis supported the first hypothesis. Younger participants performed significantly better than older respondents on the right turn index, the turns index, the sequence of turns index, and the drawn to scale index. This research is consistent with other findings on the domain of spatial memory. (Author/ABL)

Age-Related Visual and Kinesthetic Encoding Effects On Spatial Memory of a Maze-Like Floor Plan

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Running Head: Encoding Effects on Spatial Memory

Abstract

As part of an experimental research program on lifespan naturalistic and laboratory memory for spatial representations, investigators looked at interactions between the effects of visual and kinesthetic encoding and age on memory for space using a modification of the Sinnott (1987) human maze paradigm. It was hypothesized that an age effect favoring younger subjects would be present such that younger participants would perform better overall on the maze task, that older subjects would perform better on a styrofoam mock-up of the maze-like floor plan compared with a paper version, and that the addition of kinesthetic information would prove especially helpful to older participants. Eighty-three older (mean age= 68.29) and eighty-three younger (mean age= 20.89) urban respondents were asked to remember a route through a building after being presented with one of four conditions giving either realistic or paper and pencil spatial information. The second two hypotheses were not supported: however, two way ANOVAs supported the first hypothesis. Younger participants performed significantly better than older respondents on the right turn index, the turns index, the sequence of turns index, and the drawn to scale index. This research is consistent with other findings in the domain of spatial memory (Sinnott, 1987; Sinnott, Bochenek, Kim, Klein, Walters, Dishman,& Dunmeyer, 1990, in press).

Age-Related Visual and Kinesthetic Encoding Effects On Spatial Memory of a Maze-Like Floor Plan

Few researchers or lay people would deny that there are declines in memory performance as a person gets older. Negative correlations between age and performance on memory tasks have been found consistently (Zacks, 1982; Kausler, 1982). Though this may seem depressing at first glance, the investigation of age changes in memory may lead to information about basic memory processes and about what older respondents may be accomplishing cognitively or adaptively when they display poor memory.

Several theoretical issues related to aging memory deficits are worth noting. First, memory studies involving older adults have typically been experimental in nature and conducted in laboratory settings. Memory failure and its consequences are concerns of both professionals and older adults, but as Hartley, Harker, and Walsh (1980) have stated, it is not known how ecologically valid some of the tasks on which older adults show decline may be. Furthermore, Neisser (1978 & 1982) has argued that orthodox memory research has shown us too little. Cavanaugh (1982) and Sinnott (1986; 1989 a & b) argue for more naturalistic ethological studies combined with traditional experimental approaches.

Second, a researcher's approach to memory theory seems to influence and even limit research results, in that questions asked tend to be biased in support of the theoretical perspective used.

For example, questions raised from the associative model would be quite different than those raised by the information processing model. The associative model is based on a mechanistic metamodel which leads to an irreversible decrement view of aging with biological antecedents. Whereas, the information processing model is an organismic metamodel and leads to a view of age-related decrement balanced by an individual's compensation.

Subject motivation has not been directly addressed, though there has been general agreement that tasks which are unimportant to subjects can lead to poor performance. Only a handful of experimental studies have used meaningful naturalistic materials or situations, and most of these have been related to spatial memory (Baroni, Job, Peron, & Salmaso, 1980; Evans & Pezdek, 1980; Kirasic, 1983; Light & Zelinski, 1983; Perlmutter, Metzger, Nezworski, & Miller, 1981; Pezdek, 1983a; Pezdek & Evans, 1979; Salmaso, Baroni, Job & Peron, 1983; Sherman, Oliver & Titus, 1980; Waddell & Rogoff, 1981).

The success of older respondents on memory tasks also seems to depend on meaningful contexts (Hultsch, 1977). Waddell and Rogoff (1981) found that older women did as well as middle-aged women when a spatial memory task was contextually organized, though context did not appear to be as important for middle-aged adults. Older individuals in this study often needed more time to complete unstructured tasks and had difficulty developing organizational strategies (Waddell & Rogoff, 1981). It appears that older people become overwhelmed by the complex demands of tasks not put into a meaningful context. Georgemiller and Hassan (1986) stipulate that to more accurately test the spatial ability of older persons, we must do so in settings that are more familiar to older persons and use tasks that hold more meaning for them.

Spatial memory, including memory for spatial relations, is one type of memory which seems to show decline as one ages. Spatial memory can be defined as the extent to which one can accurately represent environmental or physical space using primarily mental faculties through both sensing and perceiving processes (Sinnott, et al., 1990, in press). There seems to be some disagreement over the etiology and parameters of this decline as well as the definition of the skill in question. "Decline" may be a change in mode of representation of spatial relations. It may also be the concommitant of the "turning inward" which personality theorists such as Erikson (1982) see as adaptive tasks ("development of integrity") for an aging person.

Another controversy worth considering in relation to spatial tasks is the automatic vs. effortful memory distinction. Several researchers have proposed that spatial memory is automatically encoded (Moore, Richards, & Hood, 1984; Perlmuter, Metzger, Nezworski, & Miller, 1981; Hasher & Zacks, 1979). There also exists the possibility of problematic encoding in older populations. Charness (1981) found age-related differences for the recall of chess positions, and results suggested that this deficit was due to an encoding inaccuracy and not a storage or retrieval problem. Participants in this study may have been encoding less accurate information per unit of time. The accuracy of what is encoded may be a factor in these spatial tasks which suggests that older adults may rely more heavily on effortful processes in their memory for spatial relations.

Incorporating various other memory tasks, Light and Zelinski (1983) and Pezdek (1983b) concluded that both age and test expectations affect spatial memory ability. Pezdek (1983b) explains these age differences in terms of differing encoding and rehearsal strategies used by the two age groups. These results are supported by those of Bruce and Herman (1986) in their study of spatial memory in young and older women where the older group took two trials to perform comparably to the younger group. The researchers believe this implies that the elderly require more practice than do the young possibly due to their having more difficulty using encoding strategies (Bruce & Herman, 1986).

One of the components in the process of spatial recall is the ability to interact with space (spatial orientation) in order to interpret and then remember what one has sensed. Considerable research has been conducted on how people orient themselves in order to facilitate their spatial memory processes, and this research has identified several important qualitative criteria for evaluating and predicting one's orientation performance potential. These criteria include one's ability to estimate distance and time as well as one's sense of direction (Kozlowski & Bryant, 1977). Other factors that are conducive to spatially orienting oneself are the establishment of reference points and the presence of hierarchical and clustered organization of these reference points (landmarks) as well as semantic information concerning the landmarks (Hirtle & Jonides, 1985).

Georgemiller and Hassan (1986) describe a phenomenon which they call "defective route-finding ability" as being partially caused by age. This deficit, these authors explain, can cause inaccuracy in path-tracing mazes on both paper and pencil or locomotor type. Evidence shows that elderly people with this disorder may neglect turns in one specific direction, become confused at points where a directional decision must be made, reverse left and right turns, or reproduce relative route lengths inaccurately (Georgemiller & Hassan, 1986).

Finally, what variables relate orientation to interpretation in the form of a cognitive map (Levine, Jankovic, & Palij, 1982)? Levine et al. (1982) argue that spatial information is generally interpreted and stored in a specific way and must be recalled in the same specific orientation as initially learned (much the same as state-dependent memory). This suggests that spatial judgements are easy when the layout is presented as learned initially, but the spatial judgements become more difficult when the layout is presented in a different orientation (Presson, DeLange, & Hazelrigg, 1987). Levine et al. (1982) characterize these two types of spatial learning as "aligned" and "contraligned". Presson et al. (1987) concur with previous research that certain types of spatial information (maps) consistently show orientation-specific effects; however, other types of spatial information, such as navigation of large-scale environments and nonsighted navigation of simple routes, can be coded and recalled more flexibly in an orientation-free manner that employs multiple orientations. This orientation-free learning mitigates the effects of "contraligned" presentation and recall. Also, these multiple frames of reference which facilitate more flexible learning and recall of spatial information are specific to real-world complex environments and are difficult to replicate or observe in a simple, sterile laboratory situation (Smyth & Kennedy, 1982).

The relationship between the types of spatial information, i.e., three-dimensional vs. two-dimensional, natural vs. laboratory, and the relative availability of spatial information have occasioned many research studies. It has been reported that real-world schema play an important role in encoding and memory for spatial information (Mandler & Parker, 1976).

The current investigation is part of an ongoing research program looking at various components of spatial memory. The paradigm, which has been developed for use in the program (Sinnott, 1987), is based on a real but maze-like floor plan of the Gerontology Research Center in Baltimore where participants of the Baltimore Longitudinal Study of Aging (Shock, Andres, Arenberg, Costa, Greulich, Lakatta, & Tobin, 1985) were tested. Many variations of this floor plan model can and have been designed. A styrofoam mock-up, a pencil and paper version, and a videotape version are some of the existing variations, which range from completely naturalistic to relatively abstract. The model is flexible enough to allow researchers to examine various aspects of memory for spatial relations. Previous variations of this paradigm have focused on age and attention effects in a naturalistic environment, visual cue effects in a naturalistic environment, task abstraction using a human-sized styrofoam model of the maze, and visual, verbal, and kinesthetic encoding effects using a paper and pencil model. In the present study, which is the fifth in this series of experiments, researchers examined visual, kinesthetic, and age effects on encoding using both styrofoam and paper and pencil variations of the paradigm. In this way, joint effects of age and encoding\performance modality, and plain visual vs. kinesthetically assisted visual information were examined. Looking at these variables, experimenters hypothesized that an age effect favoring younger subjects would be present such that younger participants would perform better overall on the effortful maze task. Older subjects were expected to perform better on a styrofoam mockup of the maze-like floor plan as opposed to paper versions, since that context was more naturalistic and motivating and allowed for interactive participation. It was expected that the addition of kinesthetic information would prove differentially helpful to older participants since it aids encoding. It was also expected that respondents' errors would form a meaningful pattern. If cognitive mapping was the underlying process being used, though, it was expected that the paper version would lead to better responses due to its having somewhat more alignment between stimulus and response mode.

Method

<u>Subjects</u>

One hundred sixty-six urban area respondents voluntarily participated in the study. The subject pool consisted of 83 (22 males and 61 females) students of Towson State University age 17-30 (mean age= 20.89 years) and 83 (28 males and 55 females) community dwellers age 60 and over (mean age= 68.29 years).

<u>Materials</u>

A human-sized maze was assembled in a classroom at Towson State University. It was constructed of 3'x 3'x 1" styrofoam squares which were pieced together using wooden dowels to form a 30' x 18' x 6' rectangular outer boundary. The maze interior was comprised of five 12' x 3' x 3' equidistant rectangular blocks such that from the entrance subjects could have an overview of the entire maze. The maze concluded in an "office" which consisted of a desk placed inside the fourth rectangular block from the entrance. An overview of this layout is depicted in Figure 1.

Insert Figure 1 about here

An alternate paper version of the maze consisted of an 8 1/2" x 11" scaled diagram of the human-sized maze.

A subject information sheet requesting age, sex, and handedness was used along with answer sheets consisting of predrawn rectangles for drawing the maze route.

Procedure

Subjects were randomly assigned to one of four maze conditions. An equal number of young (age 17-30) and old (age 60 and over) participants experienced each condition. After completing the necessary consent forms, respondents were read instructions by the experimenter. Respondents were asked not to speak once the experiment began and were asked to pay close attention as they would be requested to remember the route later. The route of the maze was consistent across all conditions (see Figure 1); however, the presentation varied:

1) Actual Maze involving both visual and kinesthetic components.

Upon being directed to the entrance of the styrofoam maze, participants were told that the maze represented the interior of an office building which was divided into five separate office blocks. Their goal was to find a designated office. Subjects followed an experimenter through the maze corridors until they stopped at the designated office.

2) Actual Maze involving only visual component.

The nature of the maze was explained to subjects as in condition 1. While standing at the maze entrance, participants watched as an experimenter walked through the maze corridors until he/she stopped at the designated office.

3)Abstract Paper and Pencil Maze using both visual and kinesthetic components.

Respondents were shown a scaled diagram of the maze and were told that it represented a floor plan of a rectangular building with five office blocks in it. Subjects were informed that they needed to find an office. The experimenter maneuvered the subject's finger across the diagram to the designated office.

4)Abstract Paper and Pencil Maze using only visual component.

The nature of the maze was explained to subjects as in condition 3. This time, the experimenter maneuvered his/her own finger across the diagram to the designated office.

Immediately following the maze presentation, participants were asked to complete three recall tasks: draw the route presented to them, draw the shortest, most direct route from the entrance of the maze to the designated office, and write down how they remembered what they recalled. The first two tasks were randomly administered chronologically although the remaining task was always administered last.

Scoring

The maze routes drawn by respondents were scored on a variety of measures. All measures, with the exception of the Sequence Index and Choice, were used for scoring both the actual and the short routes. The maze routes were scored as follows:

1) Left Index/Right Index- the number of left and right turns a

respondent produced was subtracted from the expected number left and right turns.

2) Turn Index- a measure of how many turns a respondent provided divided by the actual number of turns presented specific to either the actual route (12 turns) or the short route (4 turns).

3) Length of Route Index- the maze routes drawn by respondents were measured using a curvimeter map measurer.

4) Drawn to Scale Index- scored by placing a transparency with a grid over the respondents' mazes and counting the number of nonshaded squares through which the route passed. Nonshaded squares were intended to outline the expected route through the maze.

5) Sequence Index- for the actual route, the sequence index was scored as a measure of the accuracy of the respondents' series of turns. Respondents scored a point for each correct turn (expected series of turns= LRRLLLLRRRRR).

6) Choice- for the short route, the choice was scored as either (1) route contained more right turns than left turns, (2) route contained more left turns than right turns, or (3) no dominance of left or right turns.

Results

Two way ANOVAs were calculated to test effects of age and condition on each of the dependent measures. Results are reported by actual vs. shortcut routes.

Actual Route

The younger respondents performed more accurately than did the older respondents on the right turn index, $F(1,157)=12.71$, $p<.00$, on the number of turns index, $F(1,157)=10.41$, $p<.00$, on the sequence of turns index, $F(1,157)=20.31$, $p<.00$, and on the drawn to scale index, $F(1,157)=12.86$, $p<.00$, all for the actual route map. Also for the actual route map, the length of route index showed that younger participants drew significantly longer maps than did older participants, $F(1,157)=3.62$, $p<.05$; the shortest maps were drawn in the Paper Visual and Kinesthetic condition. The sequence of turns index of the actual route was also significantly affected by the experimental condition, $F(3,157)=3.24$, $p<.02$, with highest accuracy for the younger group in the Styrofoam Visual and Kinesthetic condition, and the lowest accuracy for both young and older groups in the Paper Visual and Kinesthetic condition.

Shortcut Route

For the shortcut route, the experimental condition presented affected the shorter right turn index, $F(3,145)=7.73$, $p<.00$, with subjects in the Paper Visual Only condition performing most accurately, and those in the Styrofoam Visual and

Kinesthetic condition performing least accurately. Participants in the Styrofoam conditions drew generally shorter maps than those who experienced the Paper Visual Only condition, $F(3,158)=2.67$, $p<.04$. For this same measure, younger participants drew shorter maps than did older participants, $F(1,158)=5.21$, $p<.02$. Age interacted with condition on the <u>shortcut route</u> drawn to scale index, $F(3,158)=2.58$, $p<.05$: younger subjects performed better than older subjects in both of the Paper stimulus conditions; older subjects performed best in the Paper Visual Only condition; younger subjects performed worst in the Styrofoam Visual and Kinesthetic condition.

No significant age and condition effects were found for the <u>actual route</u> left turn index, for the <u>shortcut route</u> left turn index, and for the <u>shortcut route</u> number of turns index.

Discussion

Analyses indicated that the maze task, in terms of accuracy of reproduction, proved to be a challenging measure of spatial ability for both young and older populations. Moreover, 2-way ANOVAs indicated a negative relation between age and performance across most dependent measures. Younger participants performed significantly better than older respondents on the right turns index (RI), the turns index (TI), the sequence index (SI), and the drawn to scale index (DSI). This supports our first hypothesis that younger people would outperform older individuals on the maze task, and is consistent with previous research using the Sinnott (1987) human maze paradigm (Sinnott, 1987; 1989 a&b; 1990 in press). In the case of the right turns index (RI), a possible explanation for the results could be that an overwhelming majority of the respondents claimed a right hand preference for performing everyday activities, or possibly the fact that there were more right turns in the maze route. This decline in spatial ability with age does support other current findings on spatial memory (Light et al, 1983; Permutter et al, 1981; Pezdek, 1979; and Charness, 1981).

The results of analyses using 2-way ANOVAs failed to support our second two hypotheses. The inclusion of kinesthetic information and the use of a more naturalistic environment did not aid the performance of older individuals. This study; however, is consistent with other studies using the Sinnott human maze paradigm studies, including the present one, have consistently shown age-related deficits on the maze task and, the RI and the DSI seem to be most reliable in measuring this. Further, as these studies have assessed spatial processes in both naturalistic and abstract settings in varying degree, spatial memory appears to be effortless in naturalistic settings and more effortful in the lab.

There are several factors worth considering in attempting to explain the nonsignificant results in the present study. To begin, it has been argued by the present researchers that more naturalisic settings and conditions should aid older individuals by providing a meaningful context for them to easily remember. However, it must be realized that there may have been certain processes working simultaneously and counterproductively which retarded performance in the elderly. For example, sighted navigation of small-scale environments, such as the styrofoam maze in the present study, has not been proven to allow for orientation-free encoding (Presson, DeLange, & Hazelrigg, 1987, 1989). Consequently, respondents might benefit from recalling a spatial layout in the same contextual medium as the presentation, much the same as state dependent memory. Thus, although our more naturalistic setting might have provided a meaningful context, the older respondents may not have been aided by this due to the differential mediums used in presentation and recall. This orientation-specific effect may partially explain why contraligned performance on the styrofoam maze conditions was not as good as aligned performance on the paper as good as aligned performance on the paper conditions (Presson, Delange, & Hazelrigg, 1987). Although the performance on the paper conditions was not orientation-free, the presentation and recall were aligned.

Next, the need for more elaborate contexts with more cues by older individuals should be examined more closely. In proposing that the styrofoam maze in the present study provided a more naturalistic environment which presented a "richer" context and which would lead to improved performance in older adults, it may not have occured to investigators that certain confusing properties of the maze may have also been present (Presson, Delange, & Hazelrigg, 1987). According to Cherry and Park (1989), for a particular spatial memory task to assist performance of older adults, the context of the task must be elaborate and it must be comprised of visually distinctive and meaningful stimuli. The maze, as it was used, was white, geometric, and continuous in design with no other stimuli, even though it offered more elaborate kinesthetic stimuli. Perhaps a more naturalistic visual stimulus environment with more elaborate, meaningful visual stimuli would tend to improve the performance level of the older respondents.

This stimulus effect was investigated in two earlier experiments using variations of the Sinnott human maze paradigm. Using actual hallways of a building, subjects were presented with the usual maze route. In one such experiment, old and young respondents were subjected to the same condition of being led through the building by an experimenter and then asked to recall the route and a shortcut abstraction on paper. No significant age differences in performance emerged. In a subsequent study, the effect of elaborate and meaningful visual stimuli on maze performance was investigated using a condition in which some respondents were to direct their attention to the floor instead of taking in stimuli from this real-world environment. Age differences emerged favoring the young group on the visual stimulus deprivation condition. Overall, the results of these two experiments could be interpreted to support the previous contention that the lack of elaborate, meaningful stimuli in the environment differentially affects young and older adults such that older adults' spatial memory performance is negatively effected. Thus, one of the possible reasons for the lack of evidence to support our hypothesis is that the styrofoam maze provided an environment which was, in effect, void of elaborate, meaningful stimuli.

Another point of discussion centers around why the kinesthetic component didn't aid older individuals' performance. According to the original hypothesis, the kinesthetic stimuli in both paper and styrofoam conditions would tend to assist older individuals, creating less age difference between young and old groups. However, the results revealed that both age groups did best on the Paper Visual Only condition, followed by the Paper Visual and Kinesthetic condition with the younger group performing better than the old on all conditions. It seems the methodology of administering the kinesthetic condition on the Paper Visual and Kinesthetic condition might have rendered it unlikely that it be the condition in which older respondents performed the best. In this condition, the experimenter held the respondent's hand as he/she guided the respondent through the 8 1/2" x 11" paper abstraction of the maze. This distracting and visual blocking effect of two hands placed simultaneously on a relatively small area could have deleteriously effected the performance of both age groups. This phenomenon could also be explained by applying the structural vs. operational capacities distinction. According to Salthouse and Mitchell (1989), structural capacity, which is the maximum number of informational units that can be temporarily stored, shows no significant decline with age; however, declines have been shown in operational capacity or the number of processing operations that can be executed while simultaneously preserving the products of earlier processing. One could infer that the distraction or visual blocking that occurred in the Paper Visual and Kinesthetic condition disrupted this contiguous operational process, making it more difficult for both age groups, and particularly the older adults, to integrate all of the components of the maze into a comprehensive whole. The elderly may have done better on the Styrofoam Visual Only condition because they were overwhelmed in the Styrofoam Visual and Kinesthetic condition, trying to maneuver through it and taking in directional information at the same time. The Styrofoam Visual Only condition may have been an easier task in that all they have to do was stand and observe the experimenter walking through the maze.

The outcome of the present study as well as previous research using the Sinnott human maze paradigm, should serve to guide future research in this domain. The research possibilities are seemingly endless. One possible area of research that would be a direct outgrowth of previous experimentation would be to measure the effect of visual cues using the styrofoam maze. Providing visual cues should provide a more meaningful stimulus environment which would enhance older respondents' performance. The styrofoam maze could prove to be a useful tool in examining the importance of context. Studies using model town or landscape layouts, as exemplified by Light and Zelinski (1988), are inherently meaningful, and therefore, context conditions cannot be readily controlled. The use of stimulus-free, meaningless environments which can be modified to be meaningful, such as the styrofoam maze, and exemplified by Cherry and Park (1989), could lead to more valid and reliable results. The styrofoam maze could allow for experimental control while providing a certain degree of naturalism which is ideal according to Sinnott (1986, 1989 a&b) and Cavanaugh (1982). Once a clearer context with meaningful stimuli is established, then the possible importance of kinesthetic information can be further investigated. Perhaps the addition of kinesthetic information does aid individuals in remembering, especially older individuals. Finally, there is the possibility of using the styrofoam maze to examine the relationship between encoding and recall modalities. For instance, a study could be designed which could employ the use of the 3-dimensional styrofoam maze for both presentation and recall, rather than giving subjects a 3-dimensional presentation with a 2-dimensional paper recall task as used in the present study. In this way, researchers can test under what conditions spatial information is orientation specific. To conclude, the Sinnott maze paradigm seems to combine naturalistic components with traditional experimental designs which continue to prove useful in understanding the complexities of spatial memory.

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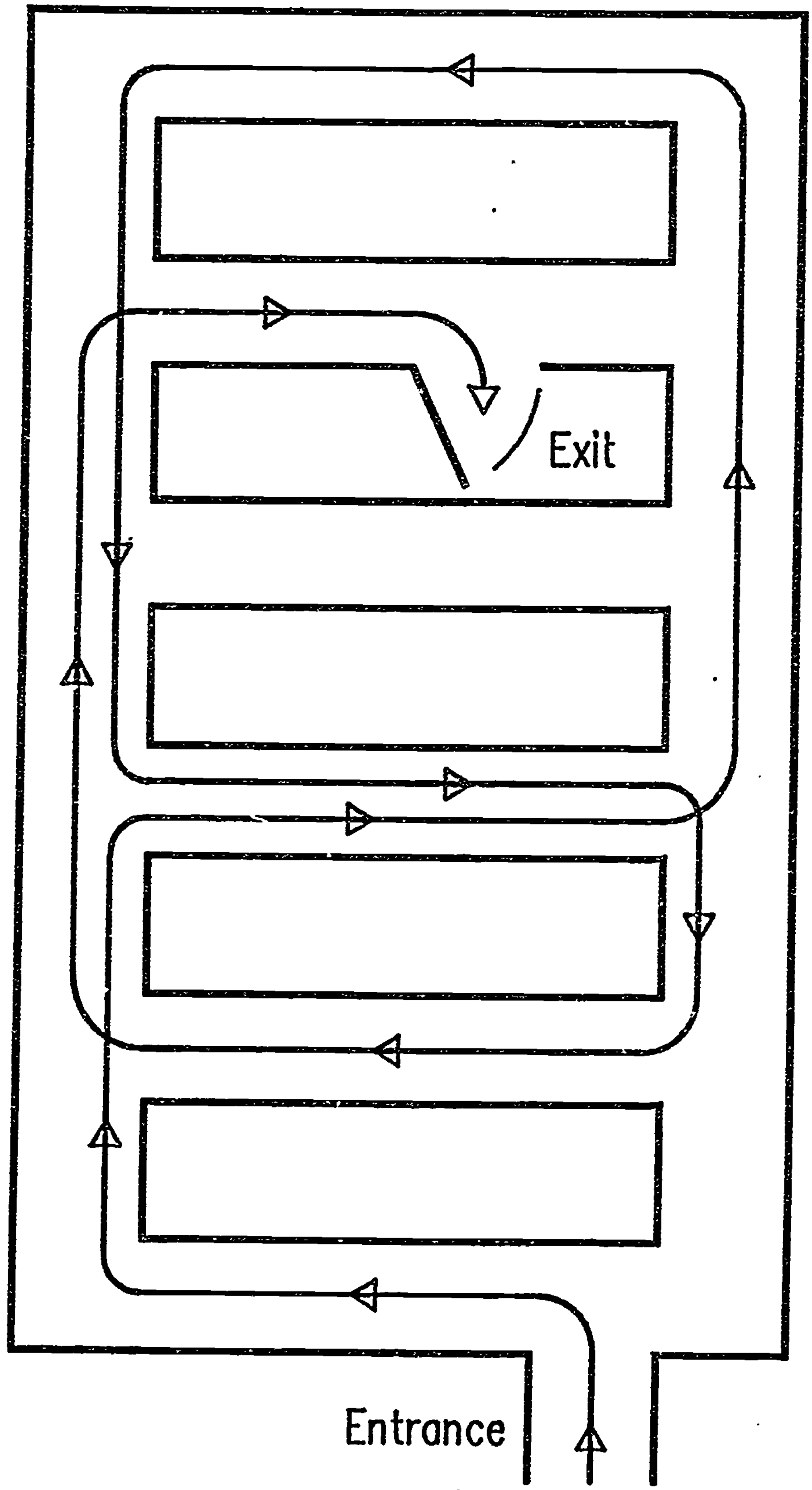
Figure Caption

Figure 1. Maze layout including the actual route used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Entrance