Cognitive distance is analyzed in relation to various elements of the built environment. The basis for accepting a power function as the underlying functional relationship between cognitive distance and its objective counterpart is discussed. This counterpart has been assumed to be objective distance. Evidence is presented to indicate that cognition of distance is based upon travel time rather than upon objective distance or upon objective distance modified by other elements of the built environment.

TRAVEL TIME AS THE BASIS OF COGNITIVE DISTANCE*

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DISTANCE cognition, as the principle spatial component of individual cognitive representations of the environment, has received considerable attention [3, 5, 6, 13, 24]. Research in this area has emphasized the determination of a functional relationship between cognitive and objective distance and the examination of various factors that are thought to modify this relationship. A power function has been generally accepted as the underlying functional relationship between cognitive distance and its objective counterpart. This acceptance is based upon empirical evidence [2] as well as upon a consensus among psychologists favoring the power function as the psychophysical law [10].

Although it has been assumed that objective distance is the most significant factor in the cognition of distance, empirical research has made it obvious that other factors are involved. Numerous additional factors have been suggested as exerting an influence on cognition of distance. These factors have been categorized by Burnett and Briggs as: (1) stimulus-centered factors, in which cognitive distance is a function of environmental features; (2) subject-centered factors, in which cognitive distance is a function of the individual; and (3) subject/stimulus-centered factors, in which cognitive distance is a function of interactions between the individual and environmental features [5].

Because they include objective distance, stimulus-centered factors are the most significant group and are the focus of the present study. Stimulus-centered factors suggested in the literature include objective distance [3, 12], number of turns [3, 11], number of stops [3], number of nodes [3], and barriers to travel [7, 16]. The concentration on this set of factors is simply an extension of the concept of a functional relationship between cognitive and objective distance to include the effects of inconvenience or delay upon this relationship.

The underlying assumption in research dealing with stimulus-centered factors is that an individual's cognition of distance is based primarily upon objective distance between locations. This assumption is doubtful, at least in the case of intra-urban distance cognition, in which time distance is generally considered more important than objective distance [4]. If the importance of travel time is thus recognized, cognition of distance can be examined from two points of view. The first, pursued by Burnett [4], is that a distinction should be made between cognition of objective distance and cognition of time distance. It is assumed that cognition of time will be more useful than the cognition of objective distance in explaining spatial behavior. An alternative approach taken here is that the isolation of cognition of time distance from that of objective distance is somewhat artificial; the cognition of distance is a process that integrates both objective and time measures and

* I would like to thank George F. McCleary Jr. for his advice at various stages of the study as well as for his comments on earlier drafts of this paper.
therefore directly reflects the relative importance of these factors to the individual in a given situation.

It is hypothesized that in urban areas, cognition of distance is, in fact, based primarily upon travel time rather than upon objective distance. In addition, it is hypothesized that the stimulus-centered factors suggested in the literature, when considered together, are simply an approximation of travel time. Therefore, as much or more of the variance in cognitive distance can be explained by travel time alone than by this combination of factors.

Data

The investigation was limited to distance cognition in consumer travel behavior, distance from home to supermarkets being the specific example considered. Limitation to one kind of trip and one kind of facility as the goal of the trip is necessary to minimize the effects upon cognitive distance of emotional involvement with the trip goal [9, 14, 23] and with the kind of facility that is the trip goal [12]. In addition, the study was limited to individuals who traveled from home to supermarkets by automobile.

Sixty randomly selected residences in Lawrence, Kansas comprised the sample. At each residence, a personal interview was conducted with the member of the household responsible for most of the grocery shopping. During the interview, each respondent named four of the ten supermarkets in Lawrence with which he or she was most familiar. The cognitive distance and the route normally traveled from the respondent's home to each store were then obtained.

An assumption in previous studies is that individuals travel the shortest or most likely routes to their destinations. This is not always the case. Approximately fifteen percent of the routes selected by respondents in the present study were not the shortest possible routes. Even when the route chosen is as short as any other route available, significant error can still be introduced into the data because routes having the same length do not necessarily have the same number of stops, turns, or nodes. By determining the specific routes followed, the present study has eliminated this source of error.

Measures of cognitive distance were obtained by a ratio-estimation procedure. Ratio estimation is a technique in which subjects are asked to estimate values of a stimulus in terms of the ratio between a standard or given value and the stimulus [20]. In this case, the standard or given value was a length of line shown to each subject and represented as the distance, by the subject's usual route, to the first store named. Subjects were instructed to place a mark on each of three other lines to represent the distances by their usual routes to the other three stores. By dividing the length of line marked for the second, third, and fourth-named stores by the length of line representing the distance to the first store, three cognitive distance ratios were calculated for each respondent.

The stimulus-centered factors chosen for comparison with cognitive distance are objective distance (i.e., road distance), stops (number of stop signs plus stop lights), turns, and nodes (number of intersections crossed along the route). Values for these variables, as well as for travel time, were determined from a map prepared prior to the collection of data. The map consisted of the street network of the city with all stop signs and stop lights indicated. Also contained on the map were values for the average travel time between each pair of adjacent intersections. An estimate of an individual's actual travel time from home to the various supermarkets was obtained by adding these values along each route traveled by the individual. Travel times and objective distances ranged from one to fifteen minutes and one-tenth to seven miles respectively. As was done for cognitive distance, ratios for each of the variables were calculated between the second, third, and fourth-named stores and the first-named store.
TABLE 1

REGRESSION OF COGNITIVE DISTANCE WITH TRAVEL TIME AND OBJECTIVE DISTANCE

<table>
<thead>
<tr>
<th></th>
<th>Travel Time</th>
<th>Road Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient ($r$)</td>
<td>0.849</td>
<td>0.801</td>
</tr>
<tr>
<td>Coefficient of determination ($r^2$)</td>
<td>0.721</td>
<td>0.642</td>
</tr>
<tr>
<td>Standard error of estimate</td>
<td>0.166</td>
<td>0.176</td>
</tr>
<tr>
<td>Regression intercept ($a$)</td>
<td>0.532</td>
<td>0.646</td>
</tr>
<tr>
<td>Regression coefficient ($b$)</td>
<td>0.737</td>
<td>0.685</td>
</tr>
</tbody>
</table>

**Power Function**

As previously stated, the power function, largely because of its identification by psychologists as the psychophysical law, has been accepted as the underlying functional relationship between cognitive and objective distance. The psychophysical law, as defined by S. S. Stevens, is an equation that relates the strength of an external stimulus to a person's impression of the subjective intensity of that stimulus [20, pp. 3–19]. Acceptance of the power function as the psychophysical law can be attributed primarily to the efforts of Stevens and his colleagues. Since 1953, Stevens and others have examined no fewer than thirty perceptual continua [18, 19, 20]. Their results indicate that the magnitude of a sensation (measured as the magnitude of a response) $R$ grows as a power function of the magnitude of a stimulus $S$,

$$R = aS^b$$

where $a$ is a scale factor depending upon the units of measurement and $b$ is a function of the sensory modality involved and determines the curvature of the function. A useful feature of the power function is that, when it is plotted in log-log coordinates, the function becomes a straight line. In terms of logarithms, the power law equation becomes

$$\log R = b \log S + \log a.$$  

This law has been shown to hold for a large number of directly perceivable stimuli (e.g., brightness of lights [17], length of lines [21], and size of graduated circles [20, pp. 145–47]). In addition, the law appears to hold for many stimuli that cannot be directly perceived (e.g., the relationship between perceived status and both annual income and years of education [20, pp. 244–47] and between perceived seriousness of crimes and the amount of money stolen [8]). In terms of distance, the power function has been demonstrated by Briggs [3], Bratfisch [1], and Ekman and Bratfisch [9] to provide the best explanation of the relationship between cognitive and objective distance.

In applications of the power law to cognitive distance, attempts have been made to relate $a$ and $b$ to the factors thought to influence cognitive distance. The $a$ parameter is believed to have little theoretical importance. The only attempt at a theoretical explanation of $a$ was presented by Canter and Tagg [7]. They suggested that the parameter may be a function of barriers between locations. It is suspected that barriers cause subjects to add a constant to their cognitive distance and that this constant is reflected in the $a$ parameter.

The $b$ parameter has been examined more thoroughly. In the majority of studies, $b$ has been observed to be less than one, indicating that cognitive distance increases at a decreasing rate relative to objective distance. The $b$ parameter cannot, however, be consid-
TABLE 2
MULTIPLE REGRESSION OF COGNITIVE DISTANCE WITH THE STIMULUS-CENTERED FACTORS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.826</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.683</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.170</td>
</tr>
</tbody>
</table>

TABLE 3
MULTIPLE REGRESSION OF TRAVEL TIME WITH THE STIMULUS-CENTERED FACTORS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.976</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.953</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.074</td>
</tr>
</tbody>
</table>

It is quite possible to have $b$ less than one, yet have cognitive distances greater than objective distances for all distances studied. This is generally found to be the case for the range of distances within an urban area.

**Analysis**

Based upon the theoretical and empirical evidence, it is reasonable to accept the power function as the underlying functional relationship between cognitive distance (i.e., the sensation) and the stimulus that leads to cognitive distance. The question is whether the stimulus is objective distance or travel time. To answer this question, ratios of cognitive distance, objective distance, and travel time were converted to logarithms and bivariate regression was used to examine the relationship of cognitive distance to both objective distance and travel time. Results of this analysis are summarized in Table 1.

Travel time, as hypothesized, exhibits a closer relationship to cognitive distance than does objective distance. For travel time the correlation coefficient, $r$, is found to be 0.85 but for objective distance it is 0.80 (a difference that is statistically significant at the 0.01 level of confidence). This result supports the hypothesis that the objective measure corresponding to cognitive distance is travel time rather than objective distance. As expected, cognitive distance increases at a decreasing rate relative to its objective counterpart.

In previous research, correlations between cognitive and objective distance have been higher than those reported here between cognitive distance and either travel time or objective distance. Only two of these studies, however, used “real” people rather than students as subjects. Cadwallader [6], in a Los Angeles study with nonstudents as subjects, found cognitive and objective distance to be highly correlated ($r = 0.96$). Canter and Tagg [7], however, obtained quite different results. They collected data on cognitive and objective distance in eleven cities. Using students as subjects in ten of the cities, they obtained correlations between 0.87 and 0.97. Nonstudents were selected in the remaining city, and a correlation of only 0.52 resulted. Based on these findings, Canter and Tagg made the conjecture that a discrepancy exists in the ability of students and nonstudents to estimate distance. Though this conclusion is plausible, it is also likely that a discrepancy exists in the ability to comprehend and perform on the test presented to them. A combi-
nation of these factors is assumed to be responsible for the comparatively low correlations obtained in the present investigation.

The second step in the analysis was to test the hypothesis that the stimulus-centered factors (i.e., objective distance, stops, turns, and nodes measured respectively as road distance, stop signs and lights, right and left turns, and intersections crossed) are an approximation of travel time and that travel time therefore explains as much or more of the variance in cognitive distance than do these factors taken together. Multiple regression analysis was performed between the stimulus-centered factors and both cognitive distance and travel time. Tables 2 and 3 contain the results of these analyses.

The regression between the stimulus-centered factors and cognitive distance resulted in a correlation of 0.83, slightly less than for travel time alone. The regression between travel time and these factors resulted in a correlation of 0.98. Both hypotheses therefore are supported. At least in this situation, the stimulus-centered factors yield a very close approximation to travel time. The slight advantage of travel time over the set of stimulus-centered factors, although not conclusive, further supports the contention that cognitive distance is formulated from a conception of travel time between locations rather than from a conception of objective distance modified by inconvenience.

Conclusions

Results of this study indicate that, in small urban areas with the automobile as the means of transportation, cognitive distance is more closely related to travel time than to objective distance. Intuitively it is reasonable to suggest that this generalization will also apply to larger urban areas. If this proves to be the case, it supports the suggestion by Burnett and Briggs that increased travel time accounts for higher cognitive distance close to city centers than away from them [5].

There are situations, however, in which objective distance rather than travel time is likely to have the greatest influence on cognitive distance. Examples that should be examined include trips in which walking is the mode of travel or in which the scale is inter-rather than intra-urban. In the former case blocks can be easily counted. In the later case the cost of gasoline may result in objective distance becoming more important than travel time.

The focus of this study has been on stimulus-centered factors, with travel time proving to be the crucial factor. It is obvious from this and other studies, however, that neither travel time nor any other stimulus-centered factor explains all of the variance in cognitive distance. Subject- and subject/stimulus-centered factors must be considered if a complete understanding of distance cognition is to be attained.

Results of a study by Lowrey indicate that driver/nondriver status is the only subject-centered factor of importance [13]. Comparison of these results with earlier results by Lee [11] leads to confusion over the exact relationship between cognitive distance and driver/nondriver status. Experiments that specifically focus on this relationship and that control for extraneous factors may clarify this relationship.

A more fruitful area for further research appears to be the relationship between cognitive distance and subject/stimulus-centered factors. Among these factors, the most promising are familiarity with trip and destination, social-psychological barriers (e.g., political, linguistic, and economic), and emotional involvement. Several researchers have demonstrated that cognitive distances to unfamiliar places are overestimated relative to distances to familiar places [15, 22]. Political and economic barriers have also been demonstrated to result in a relative increase in cognitive distance [7]. Both familiarity and barriers may prove to be related to emotional involvement; the relationship of this to cognitive distance has been closely examined by psychologists. Ekman and Brattfisch have gone so far as to propose an inverse square root law relating the two phenomena [9]. Walmsley, starting
with this concept, was able to demonstrate that emotional involvement, and therefore cognitive distance, is closely related to the complexity of the environment [24].

The present study is a step toward understanding the influence of the built environment upon the cognition of distance. Similar investigations must be conducted at various scales and for situations in which different modes of travel are employed. Attempts can then be made to examine the relative importance of stimulus, subject, and subject/stimulus-centered factors. It is only at this point, that a complete understanding of cognitive distance can be approached.

**Literature Cited**


