QUANTIFYING THE NEIGHBORHOOD ENVIRONMENT QUALITY FOR WALKING

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1. INTRODUCTION

Walking is the healthiest, most sustainable, most accessible and cheapest form of transport available. However, to encourage more people to choose walking as a mode of transport walking environments need to be made more attractive to walk in.

The literature describes many researches that try to define both quantitative and qualitatively the quality of the walking environment. The first published works used the amount of available space per pedestrian as the measure of quality (Fruin, 1971; Pushkarev and Zupan, 1975). Later, studies started considering other factors like: attractiveness (defined by the number of shops, restaurants and general aesthetic appearance), ease of walking (taking into account the presence of obstacles and the available width of pavement area), pedestrian safety issues, continuity and condition of pavement area and adjacent vehicle traffic level (Mori and Tsukaguchi, 1987; Khisty, 1994; Sarkar, 1995, Dixon 1996; Ferreira and Sanches, 2007).

A large part of the research about the relationship between built environment factors and the quality of the environment for walking, at neighborhood level, has been developed in the context of the public health. There is a growing interest in understanding the influence of attributes of the built environment on habitual physical activity and many of these studies are specifically related to walking (Aytur, 2007; Ball, 2008; Duncan, 2005; Hoener, 2005; Humpel, 2004; Li, 2005; McCormack, 2007; Moudon, 2006; Pikora, 2002).

Researchers in the fields of planning and transportation have also investigated the impact of the built environment on the option for walking trips and created walkability indexes (Badland and Schofield, 2005; Cao et al, 2009; Sanches et al, 2009). Rodríguez (2006) provides a review of existing indices of the built environment. Guo (2009) examined the causal effect of the pedestrian environment on the utility of walking and concluded that if the environment is improved more people will be attracted to public transit and non-motorized modes of transportation, like walking

Studies that considered urban form in macro-scale (in the level of census tracts or traffic analysis zones) have associated higher population density, greater connectedness of streets (higher number of intersections) and mixed land use with higher rates of walking and bicycling trips (Cervero and Kockelman, 1997; Leslie et al, 2007).

Other researchers examined the micro-scale features of the built environment including the width of the sidewalk, the presence of amenities such as benches and trash bins, and the presence of crossing aids such as stoplights and crosswalks. Humpel (2004) found evidence that perceived aesthetic attributes, accessibility of facilities, and opportunities were positively associated with neighborhood walking.

Attributes of the built environment may be measured objectively (e.g., using geographic information systems data) and subjectively (e.g., using questionnaires). Duncan (2005) provides a review of studies that used measures of perceived environment characteristics to understand the association between neighborhoods environment and population physical activities. Hoener (2005) and Cao et al (2009) use both perceived and objective neighborhood characteristics in their analysis.

In this context, the objective of the research described in this paper was to examine the relationship between built environment factors (representing several dimensions of urban form) and the perceived quality of this environment for walking, at neighborhood level.

2. METHOD

Perceptions of the local neighborhood physical environment were assessed using questionnaire based on a Brazilian version of the Neighborhood Environment Walkability Scale (NEWS), validated by Malavasi (2006). The original NEWS instrument was developed for use in the USA and also included items on bicycle use (Saelens et al., 2003; Cerin, 2006). For the present study, items related specifically to bicycling were deleted.

The questionnaire (including 30 items) assessed the following environmental characteristics: a) proximity to nonresidential land uses, such as restaurants and retail stores (land use mix–diversity); b) ease of access to nonresidential uses (land use mix–access); c) street connectivity; d) walking facilities, such as sidewalks and pedestrian trails; e) aesthetic; f) pedestrian traffic safety; and g) crime safety (see Table 1).

Land use mix–diversity was assessed by the walking proximity from home to various types of stores and facilities, with responses ranging from 1 to 5 min walking distance (coded as 1) to more then 30min walking distance (coded as 5). A “don’t know” response was coded as a “5” because if it is not known whether the facility is within walking distance, the actual walk is likely more than 31 minutes. Smaller scores on land use mix–diversity indicated closer average proximity.

Table 1 – Items in the questionnaire

- How long would it take to get from your home to the nearest businesses or facilities if you walked to them? Convenience/small grocery store, Pharmacy, Bank, Restaurant
- I can do most of my shopping at local stores
- Stores are within easy walking distance of my home
- Parking is difficult in local shopping areas
- It is easy to walk to a transit stop from my home
- The streets in my neighborhood are hilly, making my neighborhood difficult to walk in
- The distance between intersections in my neighborhood is usually short
- There are many alternative routes for getting from place to place in my neighborhood
- There are sidewalks on most of the streets in my neighborhood
- The sidewalks in my neighborhood are well maintained
- There are trees along the streets in my neighborhood
- Trees give shade for the sidewalks in my neighborhood
- There are many interesting things to look at while walking in my neighborhood
- My neighborhood is generally free from litter
- There are many attractive natural sights in my neighborhood
- There are attractive buildings and homes in my neighborhood
- There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood
- There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood
- The speed of traffic on the street I live on is usually slow
- The speed of traffic on most nearby streets is usually slow
- Most drivers exceed the posted limits while driving in my neighborhood
- There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood
- The crosswalks in my neighborhood help walkers feel safe crossing busy streets
- When walking in my neighborhood there are a lot of exhaust fumes
- My neighborhood is well lit at night
- Walkers on the streets in my neighborhood can be easily seen by people in their homes
- I see and speak to other people when I am walking in my neighborhood
- There is a high crime rate in my neighborhood
- The crime rate in my neighborhood makes it unsafe to go on walks during the day
- The crime rate in my neighborhood makes it unsafe to go on walks at night

The other 29 items were rated in a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating a more favorable value of the environmental characteristic. Thus, some items had to be reversed to match the adopted scoring scale. Two items were reversed in ease of access characteristic: difficult parking and hilly streets. Street connectivity, walking facilities and aesthetics had no reverse items. Pedestrian traffic safety had four items reversed: traffic on my street, traffic on nearby streets, exceed speed limits and exhaust fumes. Crime safety had three items reversed: high crime rate, unsafe during day and unsafe at night.

The global evaluation of the walking environment in the neighborhoods was assessed by a five-point scale from 1 (very unpleasant) to 5 (very pleasant), with higher scores indicating greater neighborhood satisfaction.

3. ANALYSIS

A total of 434 individuals living a neighborhood in São Carlos - SP participated in the survey. São Carlos is a medium-sized Brazilian city with approximately 220,000 inhabitants located in the central area of the state of São Paulo, 230 km north from São Paulo (the state capital). A recent OD survey, conducted in 2007, revealed the following modal split: 37.3% by automobile, 18.7% by bus, 29.2% on foot, 3.2% by bicycle and 11.6% by other modes of transport (mainly motorcycles and school buses).

The sample was chosen by convenience among those who agreed to participate. Characteristics of participants are shown in Table 2.

Table 2 – General characteristics of the participants

Gender:	Age (years)		
Masculine: 193 (44.4%)	< 18: 22 (5.1%)	26 to 45: 165 (38.0%)	
Feminine: 241 (55.6%)	18 to 25: 137 (31.6%)	46 to 60: 90 (20.7%)	
		> 60 20 (4.6%)	

The global evaluation of the environments (How do you classify your neighborhood for walking?) is shown in Figure 1. The greater part of the participants evaluated their walking environment favorably (average 3.3, standard deviation 0.8).

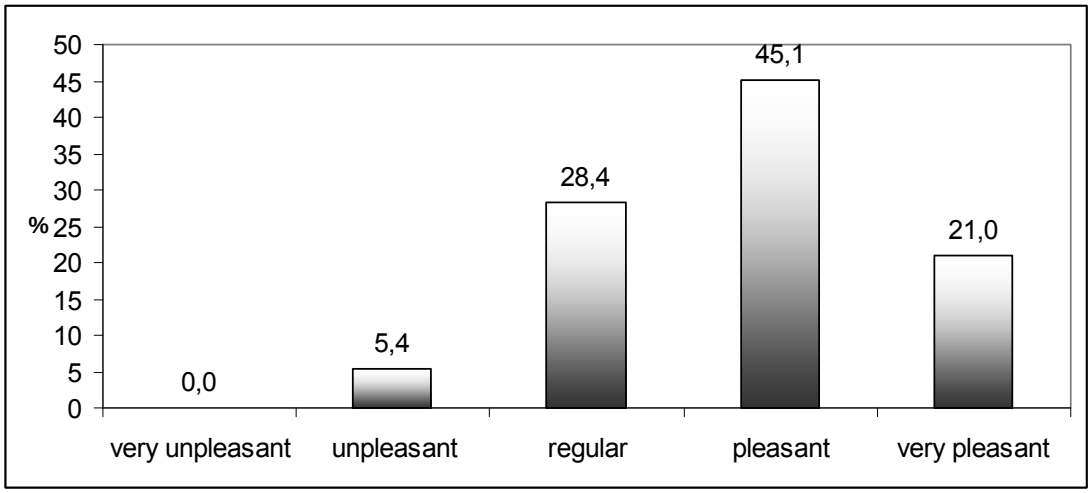

Figure 1 – Global evaluation of the walking environment

Table 3 shows the average score and the standard deviation for each item. Higher scores (closer to 5) indicate a more favorable perception of the environmental characteristic.

Accessibility to bus stops was the item with the highest score (4.70). Also the presence of sidewalks on most streets was acknowledged by many participants (score 4.00), although the condition of these sidewalks received a lower score (2.75). Most items received a score around 3 (indicating a moderate perception of the environmental quality).

Table 3 - Correlation between individual items and the global evaluation of the environment

Items	Average score	Standard Deviation	Correlation with global evaluation
Land Use	3.24	0,84	0,25
Can do most shopping at local stores	3,42	1,48	0,24
Stores are within easy walking distance	3,57	1,45	0,27
Parking is easy (*)	3,26	1,44	0,14
Easy to walk to a transit stop	4,70	0,74	0,32
Level streets (*)	3,52	1,51	0,18
Short distance between intersections	3,30	1.42	0,06
Many alternative routes	3,73	1.39	0,33
Sidewalks on most of the streets	4,00	1.40	0,39
Sidewalks are well maintained	2,75	1.42	0,48
Trees along the streets	3,40	1,46	0,61
Trees give shade for the sidewalks	3,13	1,47	0,61
Many interesting things to look at	2,62	1,41	0,66
Neighborhood is free from litter	2,57	1,45	0,53
Many attractive natural sights	2,56	1,41	0,60
Attractive buildings and homes	3,34	1,47	0,55
Light traffic on my the street (*)	2,98	1,51	0,20
Light traffic on nearby streets (*)	3,27	1,40	0,20
Slow traffic on my street	3,13	1,42	0,09
Slow traffic on nearby streets	2,56	1,36	0,17
Drivers respect speed limits (*)	2,74	1,29	0,09
There are crosswalks and pedestrian signals	2,65	1,44	0,32
Crosswalks help walkers feel safe	2,89	1,46	0,21
Little exhaust fumes (*)	3,26	1,40	0,19
Neighborhood well lit at night	2,63	1,33	0,40
Walkers can be easily seen from the homes	3,49	1,28	0,32
I meet other people when I am walking	3,30	1,43	0,16
Low crime rate in my neighborhood (*)	3,96	1,28	0,29
Safe for walking during the day (*)	2,89	1,19	0,32
Safe for walking at night (*)	3,42	1,41	0,41

(*) These items had their score reverted, so the meaning was also reverted.

To gain an overview of relationships between variables a complete correlational analysis was conducted (last column in Table 3). The strength of the correlation between the environmental characteristics varied. While “Interesting things to look at” showed a

significant positive association (0.66), “Short distance between intersections”, “Ease parking”, “Slow traffic” and “Drivers respect” indicated a non-significant association.

In general, results revealed that, aside from the items related to the aesthetic quality of the environment, all the other correlations were not very significant.

3.1 Exploratory Factor Analysis

In order to identify the underlying factors that characterize environmental quality, an exploratory Factor Analysis (principal components, with Varimax rotation) was performed.

Factor analysis is a family of multivariate methods that tries to explain inter-correlations among observable variables based on underlying factors not directly observable (Stevens, 1996). Factor analysis can be classified into two categories: confirmatory factor analysis that involves testing hypotheses and exploratory factor analysis that involves factor identification and scale construction. Exploratory factor analysis is usually the method used in human attitude analysis as the researcher is not likely to have any a prior knowledge about the attitude structure in the particular context.

For the determination of the number of factors to retain, two criteria were adopted in this study (Stevens, 1996):

- A graphical method called the Scree Test, in which the magnitudes of the eigenvalues are plotted against ordinal numbers. The recommendation is to retain all eigenvalues (and hence factors) in the sharp descent, before the line starts to level off (Figure 2).
- Retain only the most important factors (whose eingenvalues are greater then 1).

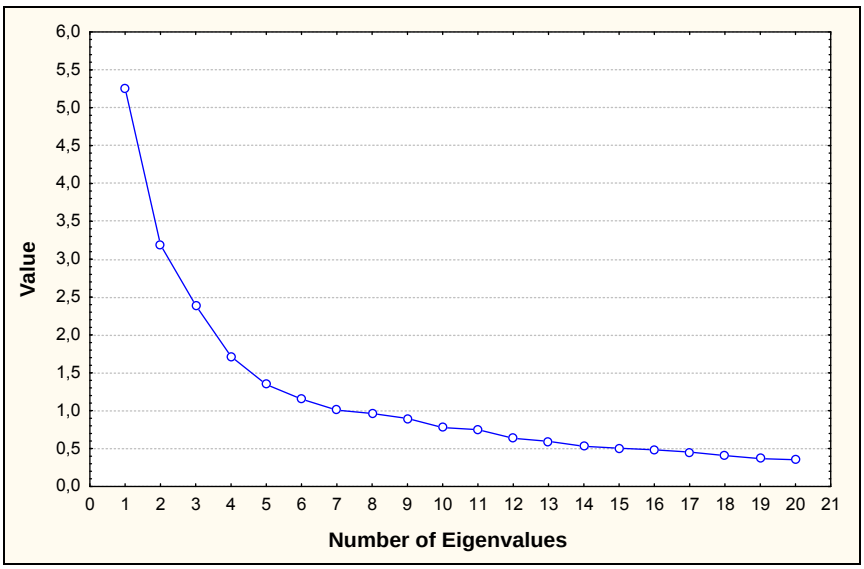

Figure 2 – Plot of eigenvalues

Based on these two criteria, four factors were retained, accounting for 50.2% of the variance. The structure of the constructs was identified from the items with exploratory factor loadings

≥ 0.4. The names of the constructs, although subjective, were given according to the items with higher factor loadings. Factor loading are shown in Table 4.

Table 4 – Factor loadings

Environmental characteristics	Subjective factor interpretations			
	Aesthetic	Safety	Accessibility	Security
Land use mix			0.6857	
Can do most shopping at local stores			0.7152	
Stores are within easy walking distance			0.7368	
Easy to walk to a transit stop			0.4726	
Many alternative routes			0.4723	
Sidewalks on most of the streets			0.7340	
Sidewalks are well maintained	0.4532			
Trees along the streets	0.7382			
Trees give shade for the sidewalks	0.7713			
Many interesting things to look at	0.7442			
Neighborhood is free from litter	0.5371			
Many attractive natural sights	0.7959			
Attractive buildings and homes	0.7037			
Light traffic on my the street		0.7405		
Light traffic on nearby streets		0.6596		
Slow traffic on my street		0.6767		
Slow traffic on nearby streets		0.6440		
Drivers respect speed limits		0.6330		
Little exhaust fumes		0.4714		
Neighborhood well lit at night				0.5054
Low crime rate in my neighborhood				0.7243
Safe for walking during the day				0.8071
Safe for walking at night				0.8422
Prp. total variation explained	0.1483	0.1174	0.1419	0.0945
Eigenvalue	5.256	3.190	2.391	1.714
Cronbach's alpha	0.88	0.76	0.79	0.72

Factor loadings < 0.40 are left blank.

Almost all items loaded high (≥ 0.4) on one factor, except for "There are crosswalks and pedestrian signals" and "Walkers can be easily seen from the homes", which did not load on any factor and hence, were excluded from the analysis.

One factor loaded high on "Land use mix", "Can do most shopping at local stores", "Stores are within easy walking distance", "Easy to walk to a transit stop", "Many alternative routes", "Sidewalks on most of the streets" and "There are crosswalks and pedestrian signals" and was interpreted as "Accessibility".

A second factor loaded on "Sidewalks are well maintained", "Trees along the streets", "Trees give shade for the sidewalks", "Many interesting things to look at", "Neighborhood is free from

litter", "Many attractive natural sights" and "Attractive buildings and homes". This was interpreted as "Aesthetic".

A third factor loaded on "Light traffic on my the street", "Light traffic on nearby streets", "Slow traffic on my street", "Slow traffic on nearby streets", "Drivers respect speed limits" and "Little exhaust fumes" and was called "Safety.

A fourth factor was identified as "Crime Safety" or "Security" because it loaded high on "Neighborhood well lit at night", "Low crime rate in my neighborhood", "Safe for walking during the day" and "Safe for walking at night.

Factor loadings range from 0.45 to 0.84 and together they explain 50.9% of the total data variance. Cronbach's alpha coefficient of internal consistency was calculated for each factor. All scores were above the 0.70 recommended level: Accessibility: 0.79; Aesthetic: 0.88; Safety: 0.76 and Security: 0.72.

Next, scores for the four factors were estimated for each of 434 participants of the survey. These factor scores essentially constitute four new variables, which are estimates of the underlying factors for each participant. These scores were standardized from normal z values (Equation 1).

$$z = \frac{x - \bar{x}}{SD} \quad (1)$$

Where:

z = score $\bar{x}$ = average
x = original value SD = standard deviation

The standardization procedure converts each factor value to a scale between $\approx$-3 to $\approx$+3. These scores may be interpreted as the evaluation of each factor by the 434 participants of the survey. Thus, a score of 3 indicates a very positive evaluation, while a score equal to -3 indicates a very negative evaluation.

A t-test revealed no significant gender difference for any of the factors scores. Also an ANOVA resulted in no difference among age groups for the four factors scores.

Figure 3 shows the frequency distribution of scores for the four factors. It can be seen that for all the factors (accessibility, aesthetic, safety and security) there are only a few very positive or very negative evaluations. Most of the evaluations are in the middle range with a tendency to the positive side.

To estimate an equation that relates the "Global evaluation of the environment" to these four factors, a linear regression was performed. Since the Varimax method is an orthogonal rotation method, the factor scores are truly independent and not correlated with one another. The results of the regression are presented in Table 5.

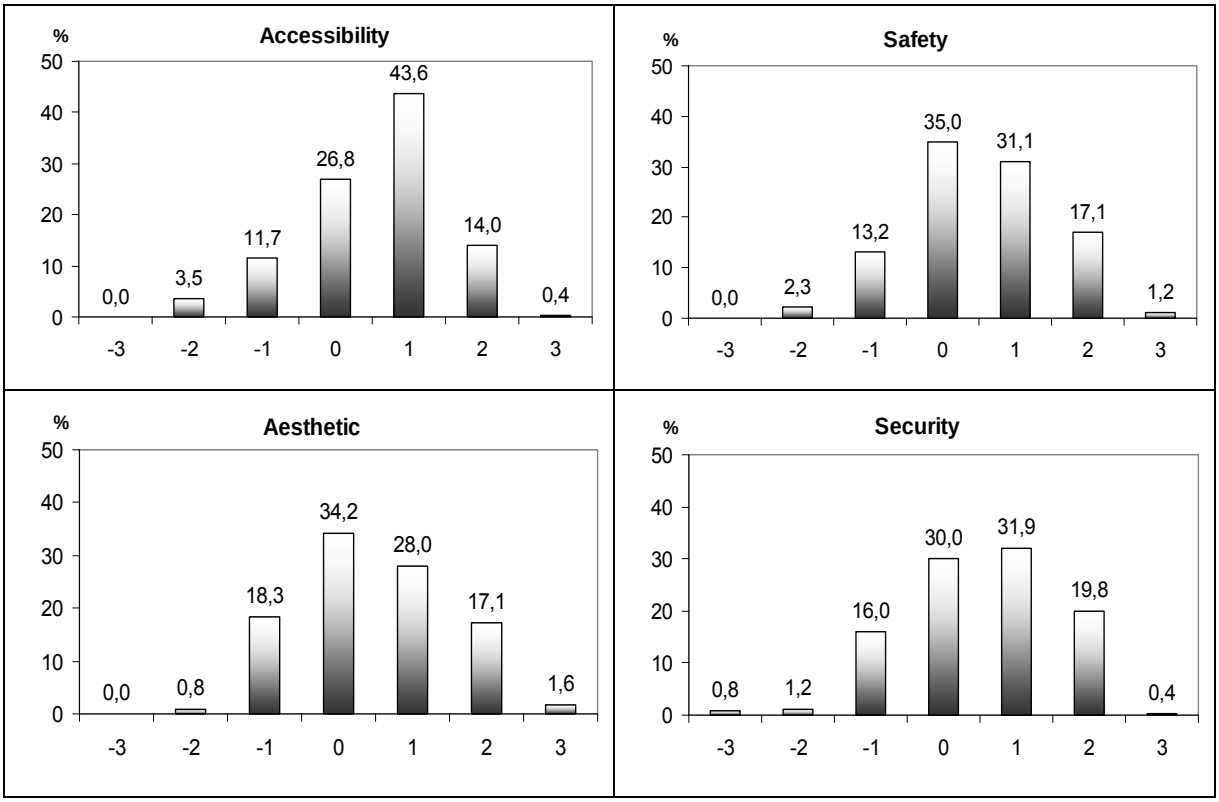

Figure 3 - Frequency distribution of scores for the four factors

Table 5 - Regression Results

	Coefficient	t-statistic	Significance level
Constant	3,3357	137.2906	7,4E-239
Accessibility	0,2938	12.0689	9E-27
Safety	0,1143	4.6946	4,39E-06
Aesthetic	0,5812	23.8769	1,19E-66
Security	0,2323	9.5426	1,27E-18
R^2	0.7669		

Table 5 shows that environmental quality was positively associated with accessibility (having more destinations within walking distance of one's home). Safety did not prove to be an important influence on neighborhood walking environmental quality for this sample of participants. This could be attributable to participants perceiving that they live in area where traffic is not a problem.

The four factors (accessibility, safety, aesthetic and security) are statistically significant. The regression coefficients indicate that higher accessibility, higher safety, higher aesthetic quality and higher security are associated with better evaluation of the walking environment. Aesthetic is the factor with the higher coefficient and, therefore, the one that has the strongest influence on the quality of the environment.

Nevertheless, interpreting the magnitude of the effect the factor variables is difficult. If the aesthetic quality is important, is it because of one or more of its characteristics: sidewalks well maintained, shady trees along the streets, many interesting things to look at neighborhood is free from litter, attractive natural sights or attractive buildings and homes?

The use of factors is helpful for capturing the underlying dimensions of the walking environment by reducing the number of variables. However, for policy-makers and practitioners, more information may be necessary.

4. CONCLUSIONS

The present exploratory study aimed to assess the relationship between built environment factors (representing several dimensions of urban form) and the perceived quality of this environment for walking, at neighborhood level.

The results of the analyses yielded four reliably and objectively measured environment factors: ease of access, safety, aesthetic and security.

An unexpected finding was that, of the four perceived environment factors, aesthetic demonstrated the strongest association with environmental walking quality. The study suggests that neighborhoods with high aesthetic quality are considered more walkable and are likely to increase non motorized mobility. It contrasts with other studies where weak associations were found for perceived environmental attributes.

The results also suggest that each of these environmental characteristics contributes independently to neighborhood walking. In addition, the amount of variance explained by the combination of these neighborhood-level variables also shows their collective contribution in explaining neighborhood environmental quality for walking.

No difference was found between men and women or among different age groups, in what concerns the evaluation of the environment.

This study has a number of limitations. Firstly, it was restricted to a single neighborhood in a Brazilian medium-sized city. The results, therefore, may not be generalized to other areas. The sample of participants was neither random nor complete. Thus, is not known how these results might be affected by a complete and random sample.

The study used only perceived measures of the environment quality. Future studies could include objectively assessed measures derived from inventories and Geographic Information Systems. Measuring both perceived and objective variables may shed light on whether it is the actual qualities of the local environment or perceptions of the environment for walking that are most likely to influence the evaluation.

Although limited, the results of this study suggest that transport policies to increase walking should consider strategies that focus on the attributes of local environments that may impact its quality (particularly aesthetics).

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