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Effect of Simplicity and Attractiveness on Route Selection for Different Journey Types

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Abstract

This study investigated the effects of six attributes, associated with simplicity or attractiveness, on route preference for three pedestrian journey types (everyday, leisure and tourist). Using stated choice preference experiments with computer generated scenes, participants were asked to choose one of a pair of routes showing either two levels of the same attribute (experiment 1) or different attributes (experiment 2). Contrary to predictions, vegetation was the most influential for both everyday and leisure journeys, and land use ranked much lower than expected in both cases. Turns ranked higher than decision points for everyday journeys as predicted, but the positions of both were lowered by initially unranked attributes. As anticipated, points of interest were most important for tourist trips, with the initially unranked attributes having less influence. This is the first time so many attributes have been compared directly, providing new information about the importance of the attributes for different journeys. ***Index terms***— Pedestrian navigation, wayfinding, simplicity, attractiveness.

1 Introduction

People plan their routes through environments every day, but what factors influence these wayfinding decisions? Although researchers have studied how humans navigate, and particularly what affects their success and ability to do this, few commercial solutions consider which factors are important when selecting a route for pedestrian travel beyond the shortest path approach. However, studies have indicated that different types of journey require different characteristics [1], and investigated the motivations or requirements for the selection of specific routes for a given purpose [2, 3]. By considering how different attributes (eg route layout and vegetation) influence pedestrians, it should become easier for navigational aids to recommend more intuitive and appropriate routes for travelling on foot.

The aim of this research is to determine how different attributes affect the selection of pedestrian routes for three wayfinding scenarios; everyday, leisure and tourist journeys. This paper reports the results of two experiments which investigated the influence that attributes have on route choice for these different types of journey. A stated preference choice approach, using three dimensional (3D) computer generated scenes and journey scenario questions, asked participants to select routes and therefore express preferences for the characteristics illustrated. These preferences were then analysed to produce a ranked list of attributes relating to each task. As future work, these ranks will be converted into algorithms to automatically suggest more appropriate pedestrian routes.

The paper is divided into three parts. The following section briefly reviews previous work, pulling together information from research into wayfinding, walkability and route aesthetics to determine which attributes should be considered. We use this research to establish hypotheses relating to the influence that the attributes have on route preference. Two experiments were then carried out to investigate these hypotheses. Lastly, the conclusions focus on the implications of this work, its limitations and how the findings can be used for future pedestrian navigation aids.

2 Background

Research into the cognitive components of wayfinding [1] indicates that when planning a route, the decision process is dependent on the type of wayfinding task to be completed. An example of this could be the differences between the daily commute to work and the route taken when going for a stroll on a summer morning. Three of the main types of wayfinding tasks are [4, 5]:

Everyday Navigation - Trips performed regularly such as the daily commute to work, or visiting the local shops.

Recreational Trips - Typically for exercise or pleasure; aesthetically pleasing.

Tourism - A typical example of this would be an individual visiting an area to see the 'sights'.

A fourth type of journey, business trips, may be considered to have many of the same characteristics as everyday journeys, and was therefore excluded from this study.

Many criteria are known to influence navigational decisions (see [2, 6, 7, 8] for examples). The criteria associated with distance have already been investigated and are employed extensively by existing route recommendation systems, and those with a time-dependent component are difficult to represent in static virtual scenes [6, 7]. The experiments in the present article will focus on the physical attributes of route attractiveness and simplicity, as described below.

Attractiveness is associated with the areas surrounding and the views visible when walking along a route, and to consider the likely influence of the attributes associated with attractiveness, we must look at the preference for them in everyday life. Aesthetics is a commonly stated criteria when choosing routes [2], and can be subdivided into a number of attributes such as vegetation, land use, cleanliness, maintenance, dwellings and points of interest [8]. Of these, cleanliness and maintenance are considered to be outside the scope of this research due to difficulties in representing them adequately in the types of graphic chosen for these experiments.

Simplicity in the context of wayfinding is associated with the layout of a route or environment, and the presence of cues such as landmarks. Turns (changes of direction at decision points) feature in a list of reasons given for choosing a route [2], as does initial leg length, and decision points with no turns have been shown to affect perceived distance and the likelihood of correctly traversing a route [9]. Additionally, the influence of landmarks on wayfinding success has been examined in depth, and it is now widely accepted that they form the basis for initial mental representations of an environment [10]. For this study, landmarks were considered to be equivalent to the attractiveness attribute 'points of interest', and the results of a pilot study (not reported here) indicated that the effects of initial leg length could not be examined using the 3D scenes used in the present study, as they showed participants the whole route not just the initial leg.

By considering all of these studies, and the experiential approach to be used, six attributes were selected. Two relate to route simplicity - number of turns and number of decision points, and four to attractiveness - vegetation, land use, points of interest and dwellings. Distance is not included in this study as it is already known to affect route choice, and was factored out in the design of the experiments. The following remainder of this section formulates hypotheses as to how each of the six attributes affect route choice for the three different journey types.

Increasing the number of turns has been shown to have a highly negative influence on the route chosen for everyday travel [2], however green space encourages walking to get to places [8] giving a positive influence. Also, as decision points increase perceived distance [11] and distance influences route choice [2], it would seem likely that these too would have a role. Combining these findings gives H1 (Table 1). However, there is very little research on how vegetation, points of interest or dwellings guide decisions for this wayfinding scenario. To determine the order of influence, the suggested ranking of a previous study was examined [2] as well as attributes that affect increases in perceived distance [11]. The number of turns ranked higher in route choice than aesthetics (assumed to be land use), and decision points affect perceived distance less than turns, but there is no comparison between land use and decision points, so we assume that the attributes will be ranked equal, leading to H2.

In contrast to everyday journeys, leisure routes seem to be wholly determined by their attractiveness. Walking for pleasure is thought to be directly associated with walkability [12] and therefore vegetation, dwellings and points of interest (all related to walkability) should be considered influential [12, 13]. Also, specific land use can instigate leisure travel [8], as well as generally influence it [14]. These findings result in H3. To date, no research is available on how route simplicity affects routes chosen for leisure. Unfortunately, previous studies also do not show any significance in the order of the attributes given. What evidence there is suggests that vegetation and dwellings are less important than land use [14], and that vegetation is preferred to dwellings [12]. As points of interest are not mentioned in either of these studies, this attribute will be left unranked. These predictions are combined to give the positions indicated by H4.

Points of interest are of particular importance for tourist trips [15], as they are usually the sole basis for the journey itself; however, other aspects of attractiveness may also affect this route type. Architecture or dwellings and land use have also been alluded to as influential factors [3], and studies have indicated that vegetation may sway the directions taken during this class of travel [3, 16], giving Hypothesis H5. Despite these suggestions, little indication is given about how these requirements were determined. Furthermore, as with leisure journeys, previous research has not considered how simplicity affects the choice of tourist routes. Points of interest will have the most influence on tourist routes, but only a very vague indication of the rank of the others is given in any related literature [3], and they will be considered unranked for this study leading to Hypothesis H6.

Table 1: Hypotheses of Journey Type Preference

Hypothesis	Description
H1	Everyday journeys will be affected by decision points, turns at junctions and land use.
H2	Everyday journeys will be most influenced by the number of turns, followed equally by land use and the number of decision points.
H3	Leisure journeys will be affected by land use, dwellings, vegetation and points of interest.
H4	Leisure journeys will be most influenced by land use, followed by vegetation and then dwellings. The rank position of points of interest is unknown.
H5	Tourist journeys will be affected by land use, dwellings, vegetation and points of interest.
H6	Tourist journeys will be most influenced by points of interest. The rank positions of dwellings, land use and vegetation are unknown.

The remainder of this section summarises the approaches chosen to display the attributes in virtual environments, and to test for participant preference. Computer-generated maps, scenes or virtual environments provide a controlled, safe test platform to investigate human navigation, spatial cognition and path choice in a laboratory setting [17, 18, 19, amongst others]. Virtual routes can be presented in one of two main ways; by traversing the route, or providing a single static snapshot of it. Static scenes based on three dimensional maps, also known as Worlds in Miniature [20] were selected for this research as they take a relatively short time to create, require little participant training [21], and can be used to test many participants at once. This approach presents pairs of routes with buildings and objects that are either mapped with photo-realistic textures, or are modelled in 3D to appear similar to real-world examples.

Stated preference choice experiments have been used to elicit responses to alternative scenarios in many different fields, including travel choice [22], bicycle route selection [23] and walkability evaluation [24]. The choice method offers participants two or more options via images or descriptions, and asks them to state which of these would be the most preferred. Although alternative approaches such as contingency ranking have also been used to test participant preference, they mostly rely on accuracy of available information and displaying an entire set of options at once [25]. Choice experiments offer a more flexible approach which relates directly to the tasks experienced in real-world situations.

3 Experiment 1: Which attributes affect route choice?

This experiment investigated whether the level of a single attribute has an effect on which route is chosen for one of three journey scenarios. A within participants design was used, with participants being shown 36 pairs of routes each showing different levels of an attribute. They were then asked to state which route in each pair they preferred, and the results analysed to give an overview of how the attributes affect route selection for different journey types.

3.1 Method

3.1.1 Participants.

A total of 73 individuals (19 females and 53 males, 1 withheld) participated in this experiment. They were aged 18 to 25 (mean 19.3 years, SD 1.5 years, 1 withheld), and all were either university students or members of staff. The experiment was approved by the Faculty Ethics Committee, and informed consent was provided by participants returning the completed multiple choice forms.

3.1.2 Materials.

Pairs of routes were shown side-by-side in single images connected to common start (bottom) and end (top) points as shown in Fig. 1. Each route varied by a single attribute relating to either its simplicity or attractiveness. The routes were constructed using Autodesk^{R} 3ds Max^{R} 2012 (14.0 student stand-alone version) [26], combined to create environments, and rendered to a 640x480 jpeg image file.

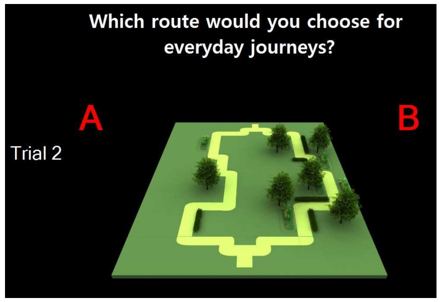
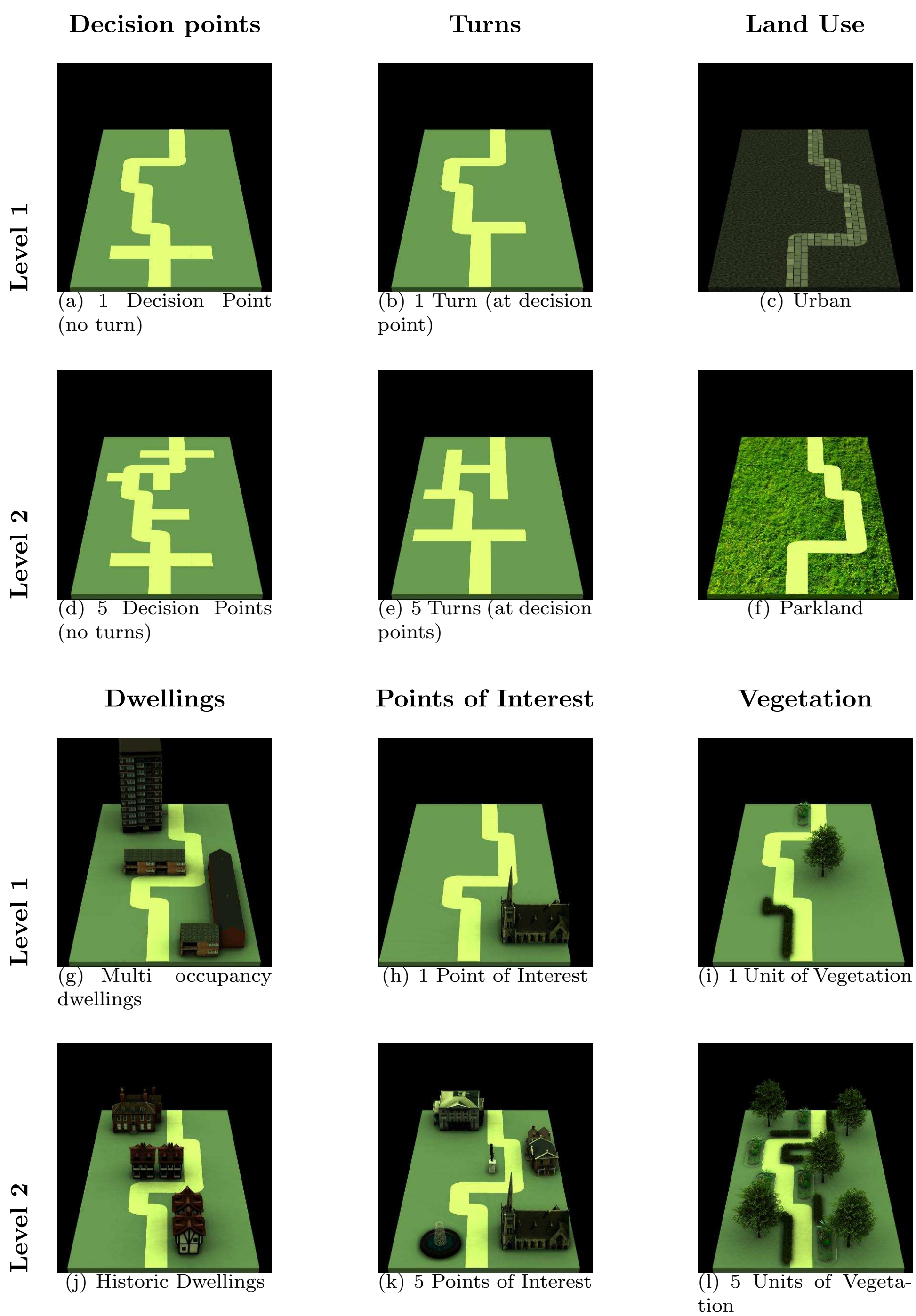


Figure 1: Example experiment 1 environment. Journey - everday, left route - vegetation level 1, right route - vegetation level 2

All of the routes were based on one of two layouts, with features added according to the attribute being illustrated as shown in Fig. 2. For attributes which required an increase in the number of elements of this type (points of interest, turns, decision points and vegetation), a single feature was added for level one and five features were added for level two. These features were selected to be typical examples of structures or elements commonly encountered in urban areas, with churches, water features, statues and public buildings chosen as points of interest, and trees, hedges and flower beds representing vegetation. For example, Fig. 1 shows two levels of vegetation with the amount of planting being increased to raise the level of attractiveness in a route.

The type rather than amount of land use or dwellings have been shown to affect attractiveness, which is reflected in the levels of these attributes as shown in Fig. 2. Multiple occupancy housing is significantly less preferred than any other form of dwelling, whereas historic homes are more preferred [27], and these each form a level for the dwellings attribute. Land use is harder to portray in a single image of these dimensions, especially without using images of housing. To prevent confusion or misunderstanding, ground coverings showing paving (urban) and grass (parkland) were selected.

Wherever possible, overlaps between feature types were avoided. However, buildings being shown as both dwellings and points of interest, and grass (which could be considered vegetation) used for parkland were considered acceptable, as similar overlaps would exist in real world environments. A pilot study was then run on the resulting routes (results not given here) to ensure that all the selected attributes and levels were discriminable. Once this had been established, a second set of routes showing the same features, but with a slightly different route layout, were produced to increase experiment validity.



(a) 1 Decision Point (no turn)
(b) 1 Turn (at decision point)
(c) Urban
(d) 5 Decision Points (no turns)
(e) 5 Turns (at decision points)
(f) Parkland
(g) Multi occupancy dwellings
(h) 1 Point of Interest
(i) 1 Unit of Vegetation
(j) Historic Dwellings
(k) 5 Points of Interest
(l) 5 Units of Vegetation

Figure 2: Artificial environments. Each image shows a single attribute level, and the features used to represent it.

3.1.3 Procedure.

Participants were each provided with a copy of a participant information sheet and a multiple choice form, to provide further information and collect their preferences. The form gave spaces for participants to record their gender and age, but they were instructed to not write their name anywhere on the sheet. In addition, two boxes were provided for each screen, including those in the training phase, one marked 'A' and one marked 'B'. During the experiment participants were asked to mark the letter corresponding to their preferred route in each trial on this form.

The experiment was divided into two phases; a training phase and a test phase that together took a total of approximately 10 minutes. During the training phase, instructions were provided to the participants, and six screens were displayed in succession, two for each of the three journey types. Questions were displayed above the routes relating to different types of journey (Figure 1), and they were provided with the following scenarios verbally:

Everyday Travel: 'Which route would you choose for everyday journeys? - This could be walking to work or uni, or if you were just popping out to the shops.'

Leisure Travel: 'Which route would you choose for leisure journeys? - This could be walking for pleasure or exercise, so say you were going for a stroll.'

Tourist Travel: 'Which route would you choose for tourist journeys? - Say you were visiting campus for a short time and wanted to explore the area, or you were taking a visitor on a tour of Leeds.'

Participants were asked to indicate that they had expressed a preference for a route before moving on to the next pair. When complete, the entire sequence of images were shown again at the same interval as those in the test, to enable participants to acclimatise to the speed with which they would have to make a selection. Participants were not asked to give responses during this rerunning, only to watch the screen.

Once this phase was complete the test algorithm was run, with the question order and sequence of the 36 images (three per attribute, for each of two route layouts) being randomly selected. The images were each displayed for 8 seconds, a simple sound was played indicating that the next image was being shown and a black screen indicated that the trial was over. The completed sheets were collected at the end and the participants were free to leave.

3.2 Results and Discussion

Of the 73 submissions the minimum percentage of completed responses was 98%, which was considered sufficient to include all participants in the analysis. The votes for each screen were gathered, and combined to give a single value for each

Table 2: Predicted (hypotheses from table 1) vs measured attribute effect for each journey type. Previously shown effects (✓), effects which are inferred from previous studies (✳), unknown effects (?) or no reported effect (✗) are compared against the effects found in experiment 1. (POIs - points of interest, DPs - decision points)

Attribute	**Everyday**		**Leisure**		**Tourist**	
	H1	**Measured**	**H3**	**Measured**	**H5**	**Measured**
Land use	✓	✓	✓	✓	✳	✓
Dwellings	?	✓	✓	✓	✳	✓
Vegetation	?	✓	✓	✓	✳	✓
POIs	?	✓	✓	✓	✳	✓
DPs	✳	✓	?	✓	?	✗
Turns	✓	✓	?	✓	?	✗

route per participant. The Friedman test for k related samples was chosen as the most appropriate non-parametric test to analyse the data. This test ranks k ordinal samples from a population according to their overall differences [28], but does not require the data to have a normal distribution. This was used to establish rank with a significance level of $p < .05$. A Wilcoxon's Signed Rank post-hoc test with a value of $p < .01$, which gives more weight to attributes having a large difference between their conditions, was also performed on the outcomes of the pairwise comparisons. The results of this analysis are shown in Fig. 3, indicating that there is a statistical significance between the different levels of all attributes for everyday and leisure journeys, and all but turns and decision points for tourist trips. These differences are compared to the predicted effects in Table 2. As in earlier research, for turns and decision points there is a negative relationship between attribute level and preference, and for all other attributes there is a positive relationship.

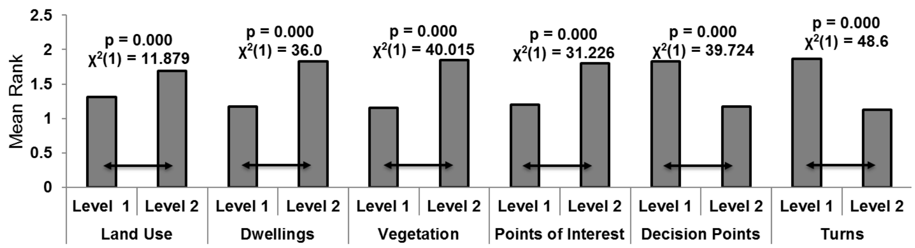
For everyday journeys, the attributes predicted by H1 and previous research [2, 11, 29] did have an influence on route choice, however vegetation, points of interest and dwellings also had an effect. Previous studies [2, for example] discuss a wayfinding criterion termed 'aesthetics', but give little or no indication of the specific attributes being included in this category. The results found by this experiment show that all of the tested attractiveness attributes affect route choice for this type of journey, rather than just land use as predicted.

In contrast to the other two journey types, for tourist trips only the attributes predicted in H5 influenced route preference. Points of interest, land use, vegetation and dwellings all affected choice as in previous studies [15, 3], but turn and decision points played no part in the decisions. This indicates that simplicity plays no role in the choice of appropriate routes for tourist travel, with attractiveness being the sole source of influence. An explanation for these results is that tourists may be more likely to carry maps, reducing complexity, and that occupants of an area may want visitors to only see the more appealing areas of their environment, giving a better impression and making them more likely to return in the future.

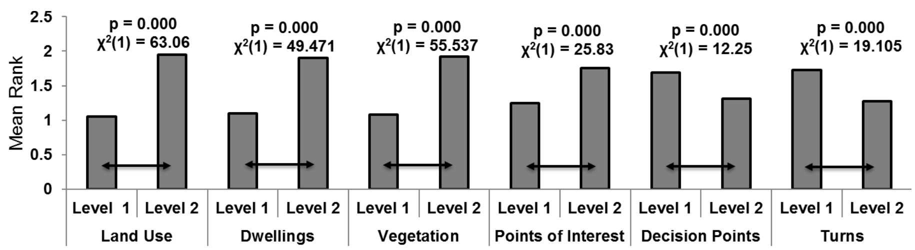
These results indicate, that to automatically select routes for these types of pedestrian wayfinding scenario in the real world, the level of each of the tested attributes should be considered. However before an automated route selection algorithm can be designed, the relative importance of each of these attributes needs to be determined.

4 Experiment 2: Order of attributes' influence

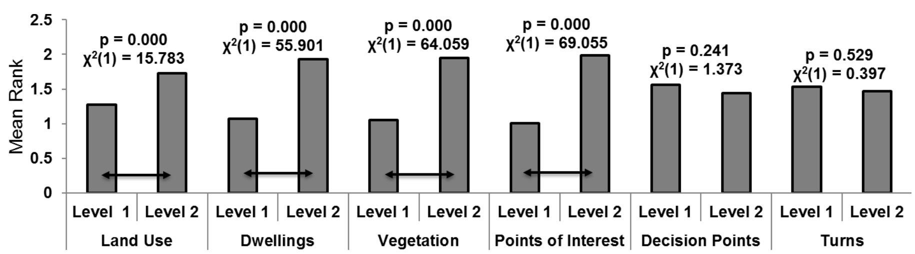
This experiment was designed to determine the order of influence of the attributes tested previously, on routes for the three types of journey. Stated choice



(a) Everyday Travel Results



(b) Leisure Travel Results



(c) Tourist Travel Results

Figure 3: Experiment 1 Friedman Test Results (rank and p values) - pairwise (Wilcoxon's) statistical significance is indicated by the arrows overlaid on the plot.

experiments were again used, but this time mixed factorial design was employed; with attribute as a within participant factor and journey type as a between participant factor. Unlike the previous experiment, the two routes displayed within each of the virtual environments contained two attributes, allowing comparison between them.

4.1 Method

To make the experiment manageable a maximum of ten minutes to complete both training and test portions was given. This experiment was divided into three separate test conditions to stay within the allocated amount of time, but still investigate all of the required attributes simultaneously. The first test examined the everyday journey scenario, the second leisure journeys, and the third tourist journeys.

4.1.1 Participants.

A total of 169 individuals (90 females and 75 males, 4 withheld) participated in this experiment. They were aged 18 to 53 (mean 23.8 years, SD 7.6 years, 4 withheld), and all were either university students or members of staff. They were divided into three groups with 55 participants for everyday journeys, 54 for leisure journeys, and 60 for tourist journeys. The experiment was approved by the Faculty Ethics Committee, and informed consent was provided by participants returning the completed multiple choice forms.

4.1.2 Materials.

The same path components, layouts and added features were used as those in the previous experiment, but in this test only the most preferred levels found in experiment 1 were included. For everyday and leisure journeys, vegetation, points of interest, land use, architecture, turns and decision points were all compared in pairs, with each route representing the most preferred level of one attribute. As the previous tests have shown that simplicity does not play a part in tourist travel, only vegetation, points of interest, dwellings and land use were considered for this type of journey. An example of the images used is shown in Fig. 4.

4.1.3 Procedure.

As in experiment 1, participants were each provided with a copy of a participant information sheet and a multiple choice form. Each part of the experiment was broken into two phases as before; a training phase and a test phase that together took a total of approximately 10 minutes. The number of images needed for the training and test phases were determined by the number of attributes being tested - for both everyday and leisure journeys, eight training and 30 test screens were used, and for tourist journeys, there were five training and 12 test screens.

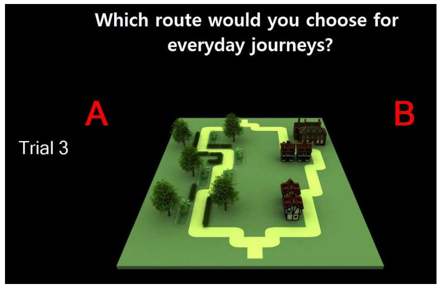


Figure 4: Example experiment 2 environment. Journey - everyday, left route - level 2 vegetation, right route - level 2 dwellings.

The same procedure for displaying the images and collecting the participant answer sheets as in experiment 1 was followed.

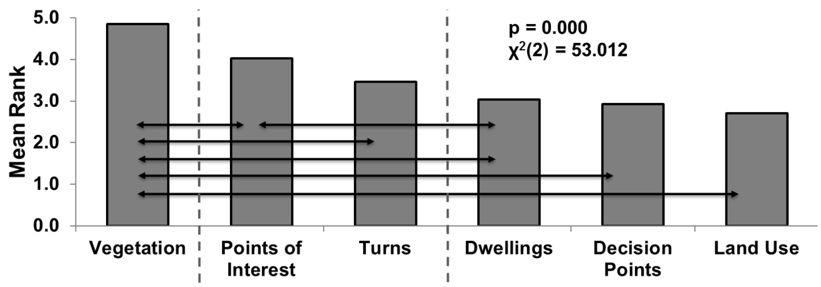
The minimum percentage of completed responses was 81%, so all 169 submissions were included in the analysis. The votes for each screen were gathered, and combined to give a single value for each attribute per participant. The results from the Friedman test ($p < .05$) and Wilcoxon's tests ($p < .01$) for each part of this experiment are shown in Fig. 5.

4.2 Results and Discussion

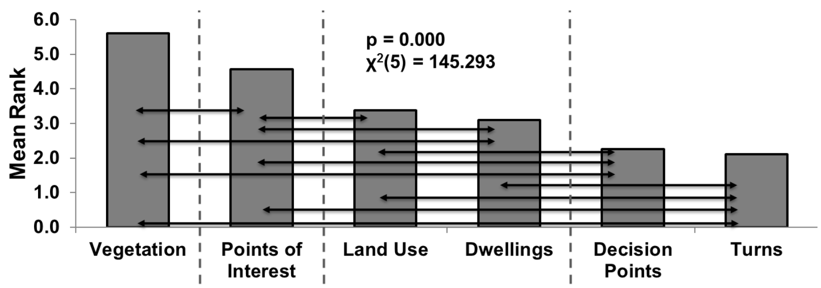
Although the Friedman test suggests a rank for each journey type, the Wilcoxon's results indicate that the order is not as clear cut as it could be. To divide the attributes into ranked lists, we started with the Friedman rank, and then split this into groups where there was Wilcoxon's significance between adjacent attributes. Finally, these groups were subdivided at any other points of statistical significance, as shown by the dashed lines on Fig. 5. The resulting ranks compared against those predicted in H2, H4 and H6, are shown in Fig. 6, which confirms some relative rankings found in previous research (the exception being vegetation vs. land use for leisure journeys) and also highlights the previously unknown importance of other attributes.

For everyday journeys, turns were found to be more important than decision points and land use, which had equal influence, as predicted by H2. However, all three occurred lower in the ranking than expected, due to the additional attributes found in experiment 1. Vegetation ranked higher than all other attributes for everyday journeys, which is somewhat surprising, as is the joint second place of points of interest. These results indicate that attractiveness attributes have a larger influence on routes for journeys of this type than expected [2]. This may indicate that participants struggle to envision the task being asked of them, or that different people look for different things when choosing routes for everyday travel. Comparisons with real-world routes would be required to investigate these theories, although consideration should be given to the differences between testing using real and virtual environments.

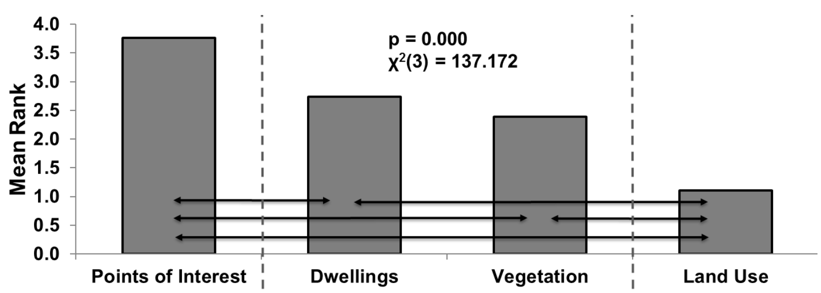
Vegetation is preferred to dwellings for leisure travel as predicted in H4 and found previously [12]; however, land use ranks only equal third rather than first as expected [14]. This may be a reflection of the images used for this attribute, and discussions held after the experiment indicated that participants had considered other factors such as weather when selecting a route. Although the relative influence of turns and decision points are not predicted in H4, they may have been assumed to follow those found in everyday routes. The equality in



(a) Everyday Travel Results



(b) Leisure Travel Results



(c) Tourist Travel Results

Figure 5: Experiment 2 Friedman Test Results (rank and p values) - pairwise (Wilcoxon's) statistical significance is indicated by the arrows overlaid on the plot. Dashed lines show where statistical significance divides the results into a rank order.

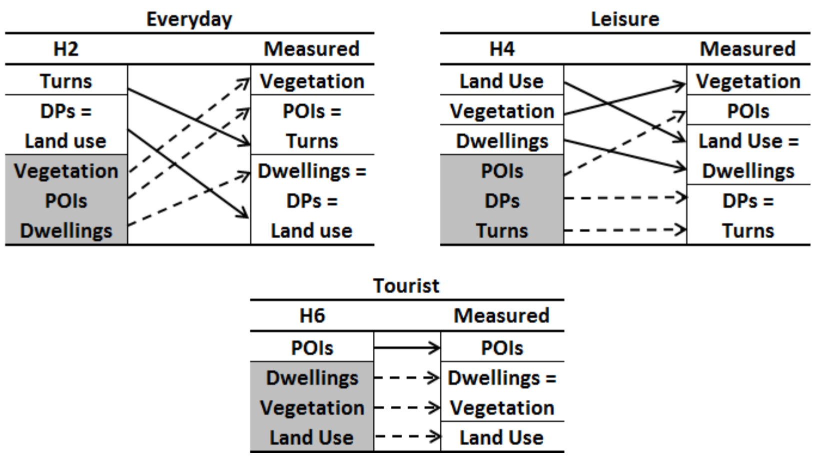


Figure 6: Experiment 2 Ranks. Predicted rank (hypotheses table 1) is compared to actual rank (right), and arrows show movement within the ranks. Grey predicted boxes and dashed lines indicate that these attributes were initially unranked. (POIs - points of interest, DPs - decision points)

the rank of these attributes may indicate that a more complex route is preferred when walking for pleasure or exercise, although as they are placed last, this influence is probably small.

As predicted in H6, points of interest play the most important role in the choice of routes for tourist travel [15], but the order of the remaining attributes was not suggested by previous work. Dwellings ranked equally next, as did vegetation. As both points of interest and dwellings may actually be destinations as well as being attributes of the environment for this type of journey, this result is not that surprising. What is more unexpected is that land use ranks last for this type of journey, although this may also be explained by participants considering outside factors as in leisure trips.

5 Conclusions

The aim of this study was to determine how selected attributes affect route selection for three types of pedestrian travel; everyday, leisure and tourist journeys. Unlike previous studies, this research investigated how a number of attributes affect the preference for a route simultaneously, providing a direct comparison between them for each journey type.

Earlier research has suggested that testing in computer-generated environments may lead to different route choices to the real world [17]. However, the ecological validity of the present study is supported by the results of experiment 1, which replicated the findings of real-world research for all attributes that have previously been studied (see Table 2).

For both everyday and leisure journeys, turns, decision points, points of interest, vegetation, land use and dwellings all contribute to the preference of a route. In both cases, this was greater than the number of attributes predicted. Attractiveness was shown to affect everyday route selection more than anticipated, and leisure journeys are influenced by simplicity which had not previously been investigated. The experiments carried out also successfully produced ranks for the influence of these attributes, which unexpectedly placed vegetation as the most important for both of these journey types. Differences between the predicted and actual placings of all remaining attributes were also seen, with land use featuring much lower than anticipated in both ranks.

Despite a lack of previous data on how they were determined, the results of the experiments on tourist journeys confirm that points of interest, vegetation, land use and dwellings all influenced route preference. They also indicate that simplicity attributes have no effect, as predicted. Furthermore, it suggests a rank for the influence of vegetation, dwellings and land use, which had not been established by earlier research.

Although this study is not an exhaustive examination of all of the factors contributing to route preference, it does suggest a basis for how people choose routes. Using these results, a system which selects routes appropriate for everyday, leisure and tourist journeys is now being developed. The ranks will be converted into algorithms which use weighted equations to generate the cost of a partial route, and employ a modified version of Dijkstra's algorithm for shortest paths [30] to select the most appropriate. Although generating the weights for these algorithms will require a complex process involving machine learning techniques, once found the method for evaluating the available routes will be straightforward. It will give a system which could be used in devices to assist journeys on foot, and unlike previous approaches (such as [31]), the resulting algorithms will produce routes according to the type of journey required.

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