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Original article

Tree selection for a virtual urban park: Comparing aided and unaided decision-making to support public engagement in greenspace design

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ABSTRACT

To meet urban resilience goals and the needs of growing populations, cities aim to develop multifunctional greenspaces and urban forests. Urban greening is seen to improve the quality of life for residents, contribute significantly to biodiversity conservation and socio-ecological resilience, and meet climate mitigation and adaptation goals. There is also a growing recognition of the importance of involving individuals and communities in the design and planning of greenspace in cities, particularly in the configuration of parks and in identifying the types of vegetation found there. In these contexts, it is increasingly common to engage the public with virtual 3D landscapes, with the ultimate goals of crowdsourcing preferences, knowledge, and patterns of use. There have been few studies to systematically examine how the public interacts with these virtual spaces, and their decision-making needs. Experts have a fluency with a broad range of ecosystem services that flow from urban greenspaces, as well as a familiarity with trees and other landscape elements. This is not the case for the public, who may instead rely on familiar and visually salient landscape attributes. This is in keeping with the concept of constructed preferences, where judgements are formed as they are elicited and are heavily influenced by available information. This study thus compares aided and unaided decision-making by the public in a virtual 3D urban park. Participants were invited to plant trees in park; some participants were provided with a brief description of a key ecosystem function of each tree (along with an illustration of that tree), other participants were only provided the illustration. Three key insights emerge from this research: (i) public tree preferences are sensitive to whether information is provided or withheld, (ii) in the absence of information, easy to evaluate characteristics (i.e., visually salient characteristics) played a large role in tree selection within the virtual urban parks, and (iii) for most participants, and consistent with other studies, aesthetics was the most important attribute guiding tree choice. These insights can support improved public engagement in landscape design and planning, particularly in crowdsourced and virtual settings.

1. Introduction

Today, 56 % of the world's population lives in cities; this is expected to increase to 70 % by the year 2050 (The World Bank, 2023). As part of wider goals for urban resilience and to meet the needs of this growing population, cities are developing multifunctional greenspaces and urban forests (Arbor Day Foundation, n.d.; United Nations Economic Commission for Europe, 2024). Urban greening is increasingly seen to improve quality of life for residents, make significant contributions to biodiversity conservation and socio-ecological resilience, and meet climate mitigation and adaptation goals (Derkzen et al., 2017; Nesbitt et al., 2017). However, while the global rate of deforestation has slowed and there is optimism about the state of the world's forests (FAO and UNEP, 2020), a recent study of urban forest cover in the United States revealed a concerning decline in many locations (Nowak and Greenfield, 2018, 2020). Key to ensuring sustained and equitably distributed forests

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in cities is the involvement of the public; both in terms of support for urban (re)forestation, as well as in terms of contributions to and care for trees in public and private settings (Barron et al., 2021; Davis and Winter, 2021).

There is a growing recognition of the importance of engaging communities in the design and planning of greenspace in cities, particularly in the configuration of parks and in selecting the vegetation found there (Campbell-Arvai and Lindquist, 2021; Connop et al., 2016). This is part of the broader movement towards community-based action research (Daepp et al., 2022) and participatory praxis (Kahila-Tani et al., 2019; Wissen et al., 2008) in landscape planning and design. This trend challenges the traditional separation between researcher and community, makes space for lived experiences (Manuel & Vigar, 2021), and promotes the co-production of knowledge (Lindquist and Campbell-Arvai, 2021; Van Berkel et al., 2022). However, in the case of urban forest management, there remains a mismatch between what the public prefers vs. that of 'experts', practitioners, and managers (Barron et al., 2016; Conway, 2016; Davis and Winter, 2021; Peckham et al., 2013). For example, while city greenspaces and urban forests may be commonly managed for regulatory services, e.g., pollution removal; aesthetic, recreational and other cultural uses are often underrepresented in these decisions (La Rosa et al., 2016; Nascimento and Shandas, 2021; Nowak et al., 2018; Riechers et al., 2017). Although some studies have shown an overlap in 'expert' and public preferences for low-cost and easily maintained urban greenspaces and forests, greater public involvement can ensure that a more comprehensive set of values and uses are included in their design and ongoing management (Faehnle et al., 2011; Nascimento and Shandas, 2021; Riechers et al., 2017).

An increasingly common approach to public participation in landscape planning and design leverages virtual video game-based 3D environments where users can interactively design the landscape, with the ultimate goal of crowdsourcing preferences, knowledge and patterns of use (Fox et al., 2022). This reflects a broader trend in the use of online participatory forums, particularly those with a spatial or GIS component, to broaden public engagement opportunities and to better understand landscape preferences through structured participatory approaches in virtual settings (Van Berkel et al., 2023; 2022). Yet there have been few studies to systematically examine how the public interacts with these virtual spaces. The need for effective integration of both visual attributes (i.e., aesthetics, recreational opportunities) and non-visual or hidden attributes (i.e., carbon sequestration, air filtration, economic benefits) in 3D landscape representations (and in formats that is appealing and understandable by a lay public) has been noted by many (Klein et al., 2015; Schirpke et al., 2023; Tyrväinen et al., 2006; Wissen Hayek et al., 2016). These studies show improved outcomes with thoughtful integration of complementary information for attributes that may not automatically or intuitively be included in planning and decision-making unless there is explicit mention, e.g. indicators of economic benefits or climate resilience (Peckham et al., 2013; Wissen et al., 2008).

1.1. Background information

To understanding how the public perceives and evaluates urban forests and forest functions, studies have used a mix of data collection approaches, e.g., via focus group discussions and open-ended questions about trees (Ordóñez et al., 2017; Speak and Salbitano, 2021) or the selection or rating of tree features and functions from a predetermined list (Jones et al., 2013; Lo et al., 2017). A review of this work also reveals that hidden or non-visually salient tree attributes may not be mentioned by the public unless they are explicitly listed at the time of elicitation.

The beauty/aesthetics of urban trees is commonly mentioned and/or most highly rated by the public, regardless of the elicitation method used (Avolio et al., 2015; Flannigan, 2005; Ordóñez Barona et al., 2016; Peckham et al., 2013; Schroeder et al., 2006). When presented in a pre-determined list, shade provision and air filtration (air quality improvement) also elicited consistently high ratings from survey participants (e.g., Jones et al., 2013; Ordóñez Barona et al., 2016; Su et al., 2022). However, carbon sequestration/climate mitigation received less attention; the few studies that explicitly included this attribute reported mixed importance ratings (Baur et al., 2016; Hegetschweiler et al., 2022; Livingstone et al., 2018). Services such as food production and stormwater management (flood control) were rarely included in these studies, or received low importance ratings when they did (Collins et al., 2019; Su et al., 2022). In studies that elicited urban forest attributes using open-ended questions, the results were more variable. Air quality improvements were mentioned in some responses to open-ended questions about urban tree benefits, although the relative importance of this attribute was mixed (Ambrose-Oji et al., 2021; Speak and Salbitano, 2021); shade provision and carbon sequestration were infrequently mentioned (Ordóñez et al., 2017; Speak and Salbitano, 2021). Unprompted, food production and stormwater management were scarcely mentioned.

This work suggests that the public relies on familiar or easily observed attributes, e.g., aesthetics, fruit production, and flowering, over less familiar or 'hidden' attributes, e.g., carbon sequestration and air filtration, when evaluating urban forests (Davis and Winter, 2021; Peckham et al., 2013). Evaluation of and support for urban trees may thus be driven by intuitive or *heuristic* decision-making, e.g. a reliance on affect (i.e., an instantaneous evaluation) (Slovic et al., 2002) or availability (i.e., salient or easily recalled features) (Tversky and Kahneman, 1974). While these and other heuristics can be a quick and reliable approach to decision-making in many settings; they can lead to inconsistencies in judgement depending on how information is framed or made available. This phenomenon, known more broadly as the construction of preference (Slovic, 1995), may partly explain the differences in 'public' and 'expert' judgements of the importance and function of urban forests (Barron et al., 2021; Suppakittpaisarn et al., 2019), as well as the differences observed from open-ended vs closed-ended elicitation of urban forest preferences (as noted above). While insensitivity to information framing is an expected outcome of 'rational' decision-making, the construction of preference is mostly observed where there is a lack of familiarity with or knowledge of the decision context; instead, preferences are 'constructed' from available information and heuristics at the time of elicitation (Lichtenstein and Slovic, 2006). Indeed, shifts or reversals in preference in response to information provision have been well-studied in a variety of contexts, e.g., evaluation of the nutritional content of foods (Gassler et al., 2023), concern about climate change (Milovanovic et al., 2022), and shifts in support for assisted migration of tree species (Findlater et al., 2020). Within the context of urban forests and green infrastructure (GI), a study of GI preferences documented a shift in public preference to more effective forms of climate-adaptive GI when a simple informational intervention was provided (Derkzen et al., 2017). However, for Davis and Winter (2021), providing information about carbon capture and climate resilience did not significantly influence public preferences for urban trees.

1.2. The present study

Building on the recent work of Davis and Winter (2021), our study was specifically designed to compare the importance of visually salient vs non-visually salient tree attributes (ecosystem services) in the presence and absence of information about those ecosystem services. Other than the study by Davis & Winter, we are unaware of any studies that have directly compared the importance of these types of tree attributes in an experimental setting. The overarching aim of this research is to improve public engagement in landscape design and planning, particularly in understanding decision needs in crowdsourced and virtual settings. The experiment presented here offers insight into tree choice within a virtual 3D urban landscape, and allows for testing users' information needs when interacting with these immersive environments. To this end, we provided some study participants with information about the ecosystem services provided by the tree species available to plant in the park (the 'aided' treatment), other participants did not receive this information (the 'unaided' treatment); both groups were provided with illustrations of available tree species. Our research questions and hypotheses are as follows:

RQ1. : What is the influence of information provision on tree selection for a virtual urban park?

Hypothesis 1. Significantly more trees with non-visually salient attributes will be selected when information is provided.

Hypothesis 2. There will be no effect of information provision on the selection of trees with visually salient attributes.

RQ2. : What is the influence of information provision on the importance ratings of tree attributes selected for a virtual urban park?

Hypothesis 3. The importance rating of non-visually salient attributes will be higher when information is provided.

Hypothesis 4. There will be no effect of information provision on the importance ratings of visually salient attributes.

2. Method

To compare aided (information about ecosystem services is provided) and unaided (no information is provided) decision-making in a virtual 3D park setting, we created a generic urban park consisting of a grassy expanse bordered by city infrastructure (e.g., roads and buildings) (Fig. 1). By asking participants to plant trees in this virtual setting, we can reveal their preferences. Recognizing that trees provide a variety of urban ecosystem services (Mitchell and Devisscher, 2022; Nesbitt et al., 2017), we varied experimentally whether participants received information about these services. A key focus was on determining whether the public can benefit from the presence of information about ecosystem services (particularly those that are not obvious or visually salient) when interacting with these virtual spaces for, e.g., participatory planning or for providing input into greenspace design.

2.1. Participants

Participants were 307 US adults recruited via the CloudResearch online survey platform (https://www.cloudresearch.com/). Quotas were used to recruit a sample that roughly approximated census data in terms of gender, age, and education level; due to the processing requirements for running the online interactive 3D landscape used in this experiment, this survey could only be accessed via a desktop or laptop computer with Google Chrome or Microsoft Edge. Participants who failed the attention checks (n = 39) were removed from the dataset.[1] Because our virtual urban park was designed using tree species commonly found in the US Midwest and Northeast, participants were recruited from the following states: Connecticut, Illinois, Indiana, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and Wisconsin. The final sample (N = 268) was 49 % male and 51 % female with a median age of 35–49 years; a median income range of $50,000–74,999; and a median education of Associate's Degree.

2.2. Virtual 3D park

The virtual 3D park used a modified version of the land.info software (Lindquist and Campbell-Arvai, 2021) developed using the Unity Real-Time Development Platform (www.unity.com). The base 3D model was city generated with the Unity asset *Fantastic City Generator* (https://assetstore.unity.com/packages/3d/environments/urban/fantastic-city-generator-157625) that provides the functionality to procedurally generate urban landscapes by adjusting different criteria e.g. city size (small, medium, large). Vegetation was generated separately using Speedtree Modeler (https://speedtree.com/) and imported into the Unity project. The focus area of the study was made editable in the Unity editor allowing 'planting' of trees in the virtual park. The project was deployed via WebGL (https://www.khronos.org/api/webgl), a cross-platform 3D graphics web standard making the interactive 3D model accessible via modern web browsers, with tree placement location data in the virtual park sent to Firebase (https://firebase.google.com/).

2.3. Procedure

Informed consent was obtained from all participants prior to commencing the online survey (using the Qualtrics survey platform: www.qualtrics.com); participants were then assigned to one of two experimental treatments within the virtual 3D urban park: (i) No Information, and (ii) Information. Participants in the 'Information' treatment saw a series of popup windows that provided a closeup of each tree diagram and (following Davis and Winter, 2021) a short written description of the key function of that tree, i.e., carbon sequestration: "*This tree is effective at capturing and storing carbon dioxide from the atmosphere*", or flower production: "*This tree produces showy flowers*" (Figs. 1–2). For participants in the 'No Information' treatment, the popup window just contained a closeup of the tree diagram. We categorized (per Davis and Winter, 2021) 'visually salient' attributes as flowering, food production (fruit), and shade; the 'non-visually salient' attributes were carbon capture, air pollution filtration, and stormwater management. The experimental setup for both experimental treatments was otherwise identical.

After completing a tutorial about the features and functions of the virtual park interface (Supplementary Materials), all participants were invited to select trees to plant in a virtual urban park setting with the prompt *"In the next part of the survey you will be selecting and planting trees within a 'virtual' urban park. There are no right or wrong choices, we are only interested in your tree selections."* Participants could select from 12 tree species (Table 1) but were limited to planting 8 trees in total.

Once participants had completed the planting task and exited the virtual urban park, they were asked two follow-up questions. Participants were first provided with a list of the names of the tree species they had selected to plant with an accompanying open-ended question to indicate why they chose those species ("*Here is a list of the number and type of tree species that you selected to plant in the virtual urban park…. Using your own words and complete sentences, tell us why you chose these particular tree species to plant.*"). Participants were next provided with a list of the 6 tree attributes (functions) used in the experiment (Table 1) and asked to rate their importance on a 6-point Likert Scale (1 = Not at all important to 5 = Very important; with 0=Not Applicable) after imagining that they had been invited to again plant trees in a nearby urban park ("*Below is a list of tree characteristics. Imagine again that you have been invited to select trees to plant in a park near you. Please use the scale below to indicate how important each characteristic is to you when selecting trees to plant in this park.*").

2.4. Analysis

Tree selection and Likert Scale responses were analyzed using the IBM SPSS Statistics software package v. 29. Two-tailed t-tests were used to test for differences in (i) the combined number of trees selected with visually salient vs non-visually salient attributes, and (ii) the importance ratings of visually salient vs non-visually salient attributes.

Open-ended responses were read multiple times by four of the

[1] Attention checks consisted of a single item embedded in a later multi-item question (not included in this analysis). This item instructed participants to 'Select Important' for this response. Participants providing nonsense responses to open-ended questions were also screened out.

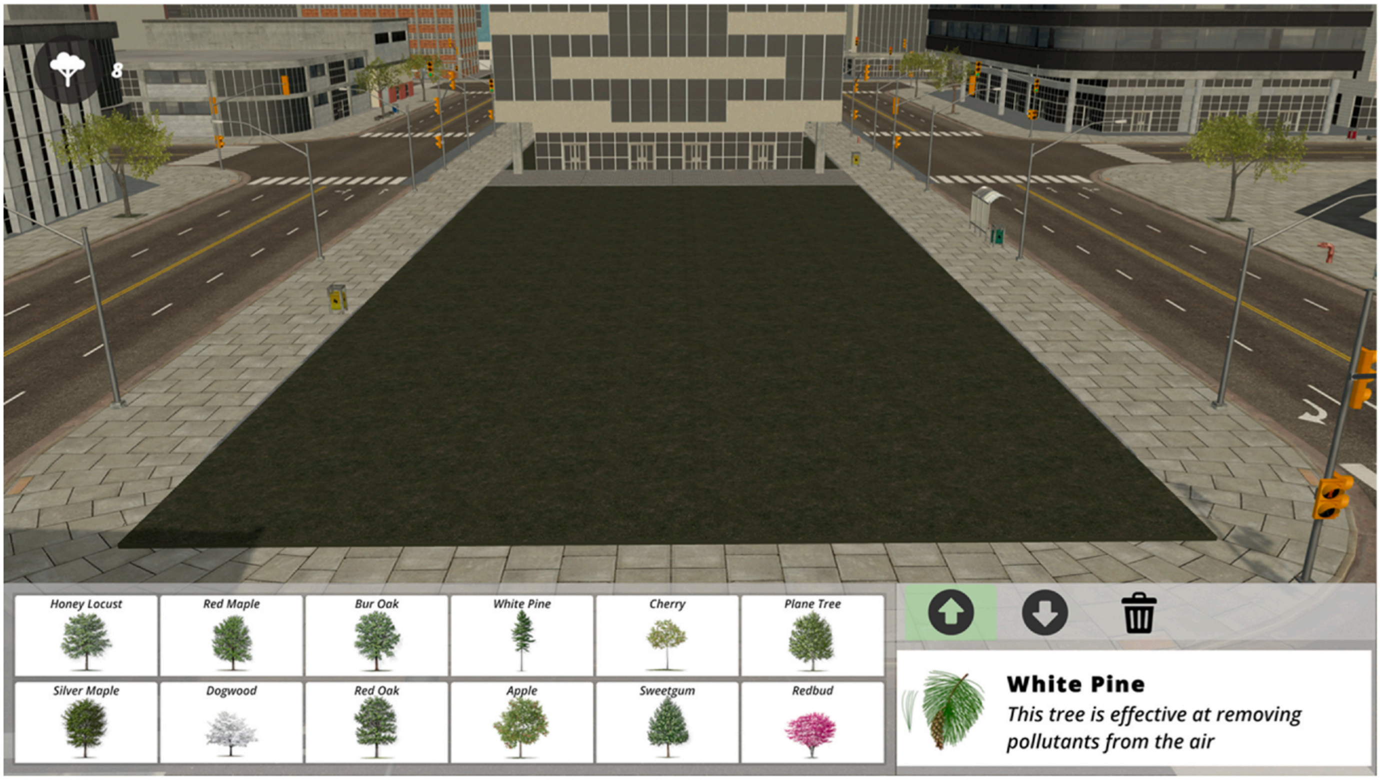

Fig. 1. View of virtual 3D urban park, as seen by study participants.

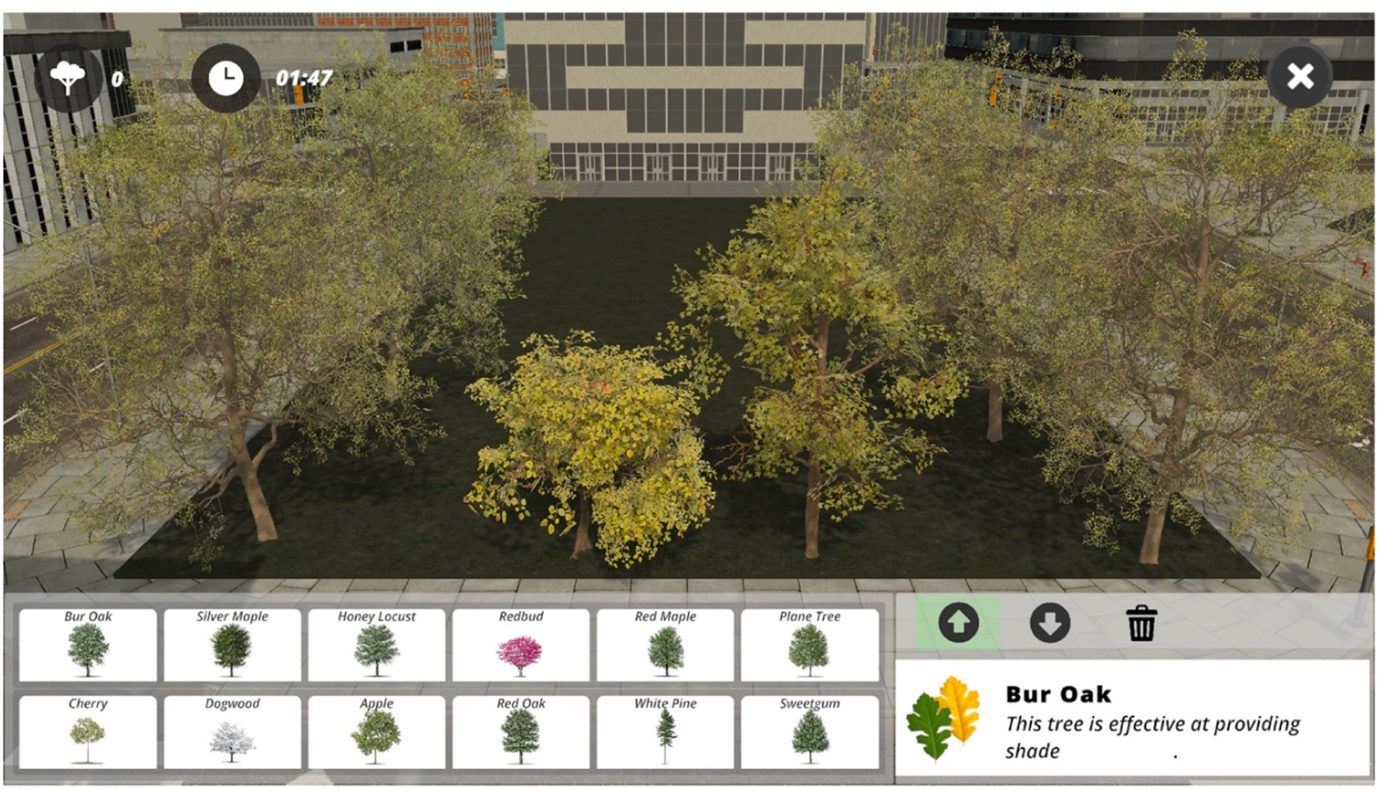

Fig. 2. View of virtual 3D urban park with an example of tree selection and placement, as created and seen by study participants; showing Apple, Bur Oak, Plane Tree, and Red Maple selections.

Table 1
Tree species available to plant in the virtual urban park[a].

Non visually salient			Visually salient		
Carbon Capture	**Air Filtration**	**Stormwater Management**	**Flowering**	**Fruit Production**	**Shade Provision**
Red Oak (*Quercus rubra*)	White Pine (*Pinus strobus*)	Honeylocust (*Gleditsia triacanthos*)	Eastern Redbud (*Cercis canadensis*)	Apple (*Malus* spp.)	Red Maple (*Acer rubrum*)
American Sweetgum (*Liquidambar styraciflua)*	London Plane Tree (*Platanus x acerifolia*)	Silver Maple (Acer saccharinum)	Dogwood (*Cornus florida*)	Cherry (*Prunus* spp.)	Bur Oak (*Quercus macrocarpa*)

[a] The tree species used in this study were selected based on published recommendations of the best species for a particular function (e.g., Yang et al., (2015). Ranking the suitability of common urban tree species for controlling PM2.5 pollution. *Atmospheric Pollution Research*, *6*(2), 267–277. https://doi.org/https://doi.org/10.5094/APR.2015.031; https://stormwater.pca.state.mn.us/index.php/Trees)

authors, and a list of codes were developed using a combined inductive and deductive approach (Thomas, 2006). The codes represented key themes that emerged in response to the open-ended question, but we also included a priori codes representing the tree attributes specified in the experimental setup (Table 1). Discrepancies in codes and coding were resolved through discussion and re-reading the open-ended responses. Once the list of codes was finalized (Table 2), the number of mentions of each code was tallied. Each response to the open-ended survey question was included as a single unit of data, multiple mentions of the same code within an individual response were counted only once. For the sake of clarity, only tree attributes mentioned by at least 10 participants (across both treatments) are included here. A full list of coded themes is included in Supplementary Materials.

3. Results

3.1. Tree selections

An average of 7.8 trees were selected in the Information treatment, and 7.6 trees were selected in the No Information treatment. There was no significant difference in the number of trees selected in the two treatments ($t = 1.41$, $p = .160$). In the ‘Information’ treatment, the most commonly selected tree species were Dogwood, Redbud, Red Maple, Plane Tree and Red Oak; in the ‘No Information’ treatment the most common choices were Dogwood, Redbud, Cherry, Red Maple, and Apple.

We first investigated Research Question 1: What is the influence of information provision on tree selection for a virtual urban park? Our hypotheses were partially supported. For H1, significantly more trees with non-visually salient attributes were selected when information was provided, in comparison to when information was not provided ($t = 7.57$, $p = .0001$). H2 was not supported in this pooled data, however. Significantly more trees with visually salient attributes were selected in the ‘no-information’ condition, than in the ‘information’ condition ($t = -6.30$, $p = .0001$) (Fig. 3). A series of post-hoc tests of the difference in the number of trees selected from each of the attributes were conducted (with appropriate Bonferroni adjustments). These t-tests revealed that significantly more trees were selected for carbon capture and air filtration (non-visually salient attributes) when information was provided ($t = 3.39$, $p = .001$, and $t = 6.58$, $p < .001$, respectively), and significantly more trees were selected for flowering and fruit production (visually salient attributes) when information was not provided ($t = -5.01$, $p < .001$ and $t = -3.42$, $p = .001$ respectively). There were no significant differences in the number of trees selected for shade (visually salient attribute) and stormwater management (non-visually salient attribute) in the two experimental treatments ($t = 1.53$, $p = .13$ and $t = 1.48$, $p = .14$, respectively) (Fig. 4). The lack of a significant difference in the number of shade trees selected in the no-information vs information conditions provided partial support for H2.

Table 2
Qualitative codes developed from open-ended responses.

Code	Brief description
Aesthetics	Trees that are beautiful, pretty or good-looking
Shade	Trees that provide shade
Air pollution	Trees that clean the air, improve air quality
Food/Fruit	Trees that provide food or fruits
Color/Fall color	Specific mention of color (leaves or flowers), or change of leaf color in fall
Benefit the environment	General mention of helping the environment
Stormwater management	Trees that control flooding and rainwater
Carbon capture	Trees that help the climate, absorb carbon dioxide
Height	Trees that are tall in height
Appropriate	Trees that are appropriate for a city park
Flowers/Fragrance	Trees that have flowers
Familiarity	Trees that are familiar, specific memories, a favoured species
Variety	Selecting different trees to provide variety or contrast
Maintenance	Trees that are easy to maintain/Avoiding trees that are ‘messy’
Sit and enjoy	Goal of sitting beneath tree, enjoying the trees

3.2. Tree attribute ratings

The hypotheses associated with Research Question 2 (What is the influence of information provision on the importance ratings of tree attributes selected for a virtual urban park?) were also partially supported. The importance rating of non-visually salient attributes was significantly higher when information was provided than when information was not provided ($t = 3.07$, $p = .002$), supporting H3 (Fig. 5). However, there was also a significant effect of information provision on the importance ratings of visually salient attributes ($t = -3.64$, $p < .001$); thus, H4 was not supported in the pooled data. A series of post-hoc tests of the difference in importance ratings of the specific tree attributes (Table 1) were conducted (with appropriate Bonferroni adjustment). There were significantly higher importance ratings for each non-visually salient attribute when information *was provided* ($t = 3.57$, $p = .0001$; $t = 1.33$, $p > .10$; and $t = 3.27$, $p = .0001$, respectively) (Fig. 6). The attributes Familiarity, Aesthetics, and Flower production received significantly higher importance ratings when information *was not provided* ($t = -2.56$, $p = .01$; $t = -4.66$, $p = .0001$; and $t = -3.01$, $p = .003$, respectively). There were no significant differences in importance ratings for Fruit production and Shade between the two information treatments ($t = -0.63$, $p > .10$ and $t = -1.57$, $p > .05$, respectively), providing partial support for H4.

3.3. Qualitative responses

From the responses to our open-ended question “*Using your own words and complete sentences, tell us why you chose these particular tree species to plant*”, there were both similarities and distinct differences in the type and frequency of attributes mentioned; these results largely reinforce the relative importance of tree attributes as revealed in participants’ choice of trees to plant. In both information treatments, aesthetics, colour, shade, and food/fruit provision were commonly

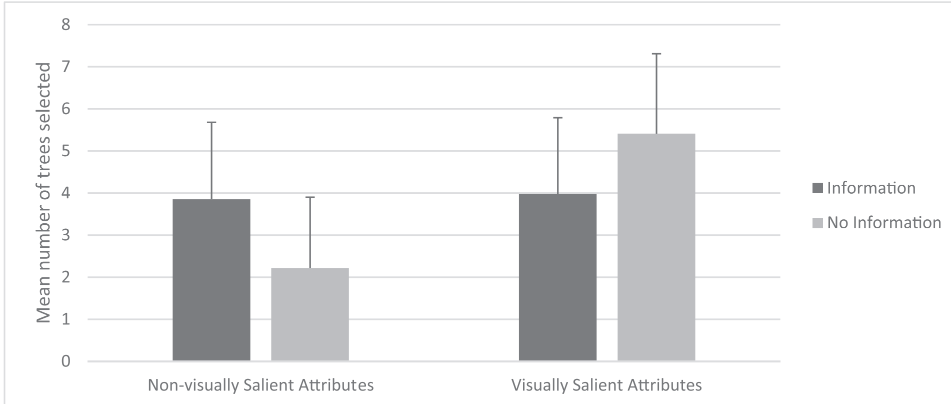

Fig. 3. Influence of information provision on the pooled number of trees with non-visually salient attributes vs visually salient attributes selected for planting in the 'virtual' park. There was a significant effect of information provision in both comparisons.

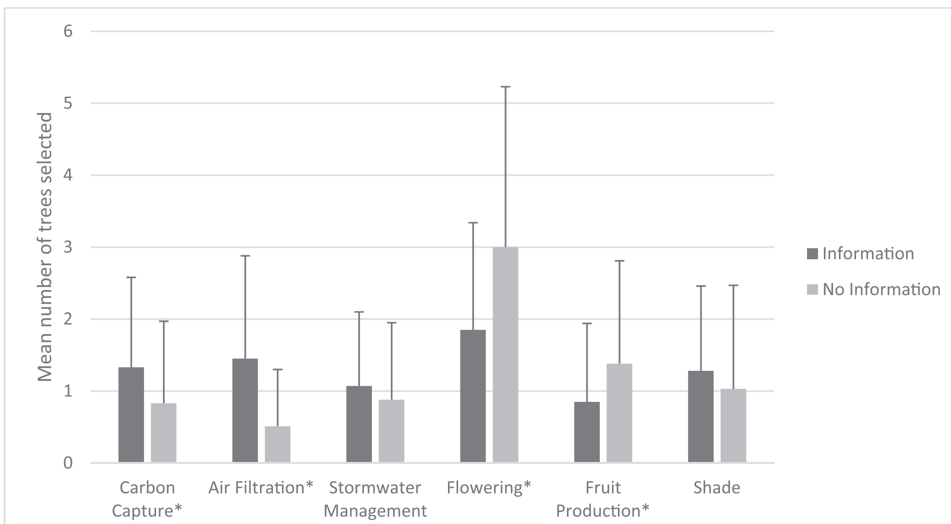

Fig. 4. Influence of information provision on the selection of trees with a specific attribute for planting in the 'virtual' park; * indicates a significant difference.

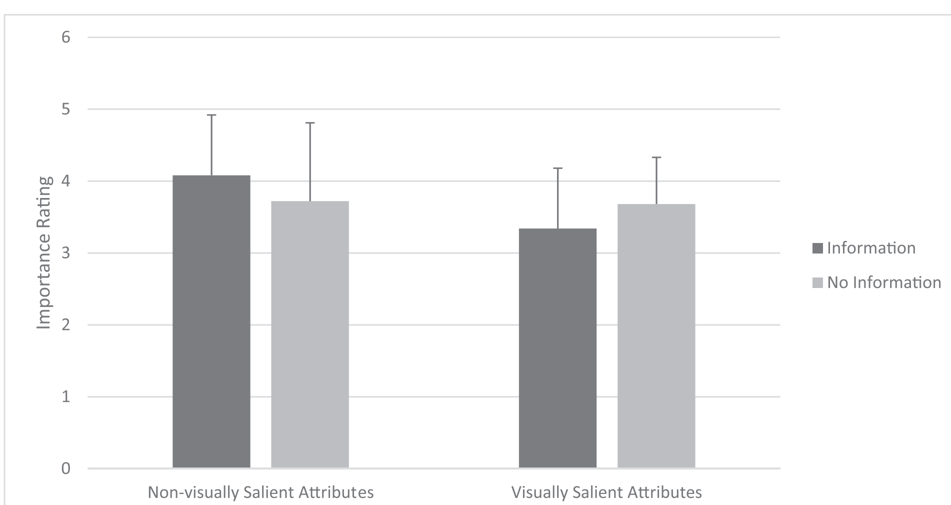

Fig. 5. Influence of information provision on the importance ratings of non-visually salient vs visually salient tree attributes. There was a significant effect of information provision in both comparisons.

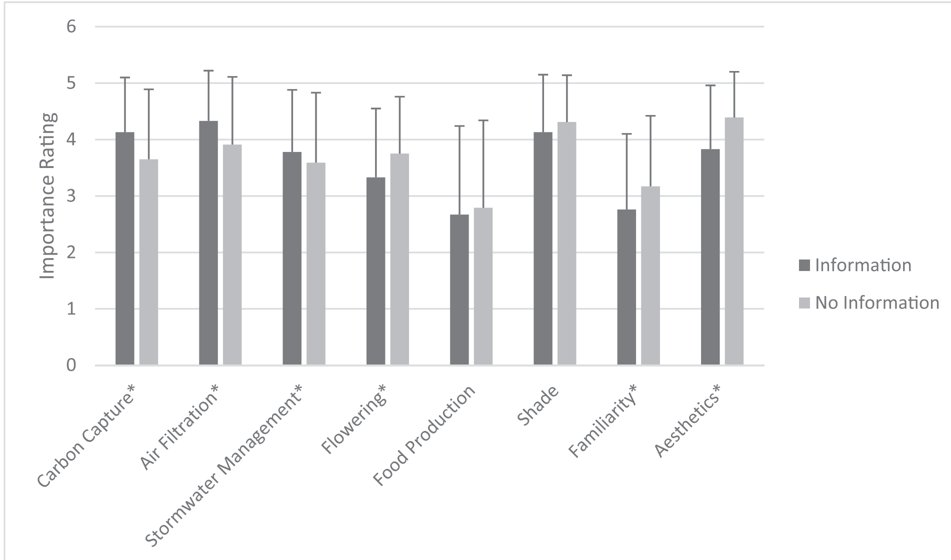

Fig. 6. Influence of information provision on the importance ratings of specific tree attributes; * indicates significant differences.

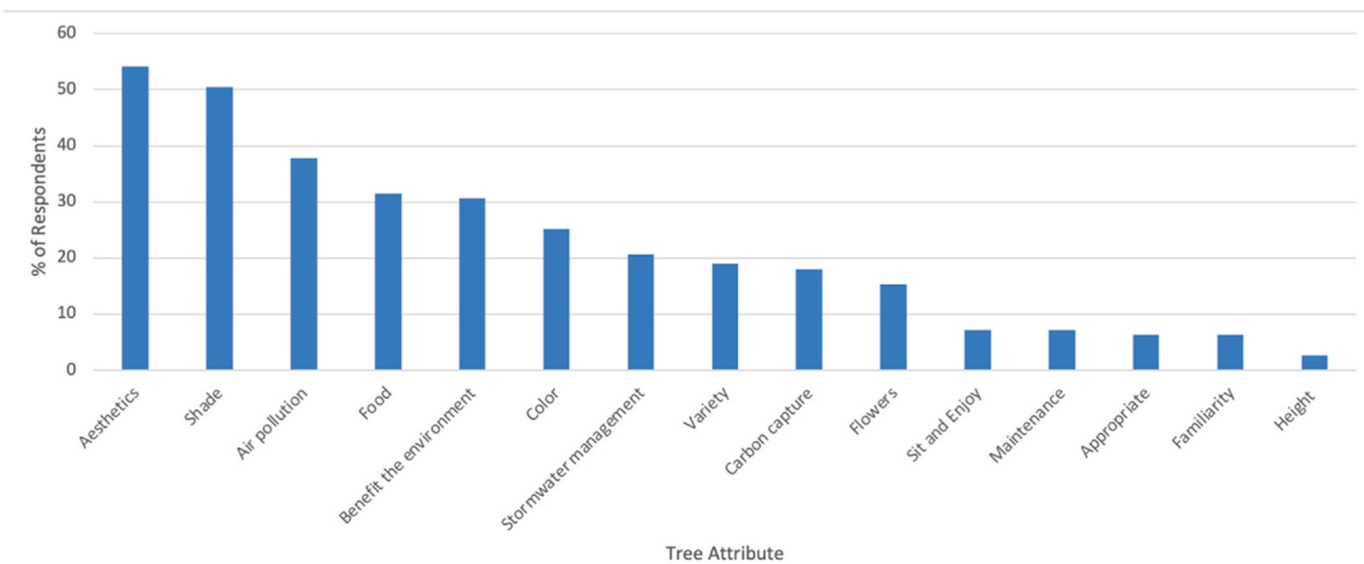

Fig. 7. Percent of respondents mentioning specific tree attributes in response to a prompt asking them to justify their tree choice(s); from the 'Information' treatment (N = 111).

mentioned in participants' written justification of their tree choices (Fig. 7 & 8). When information was provided to participants, air filtration, carbon capture and stormwater management were more frequently mentioned (i.e., 37.8 %, 18 %, and 20.7 % of responses, respectively); a general 'benefitting the environment' was also a common response (30.6 %) (Fig. 7). When information was not provided, other tree attributes like variety, shade, and height were commonly mentioned reasons (30.7 %, 27.3 %, and 17 %, respectively). Carbon capture and air filtration were mentioned infrequently, whereas stormwater management and helping the environment were not mentioned (Fig. 8). Trees that produce flowers received moderate mention in the no-information treatment (6th most mentioned attribute), whereas that attribute was less frequently mentioned in the information treatment (10th most mentioned attribute). We additionally observed longer responses in the 'information' treatment; a more detailed qualitative analysis of these open-ended responses is forthcoming.

4. Discussion

This study had as its focus an investigation into public preferences for tree ecosystem services in a virtual urban park. Inspired by the long tradition of visualization in participatory planning and ecosystem management, and building on research by Davis and Winter (2021), we utilized a tree planting exercise within the virtual urban park to compare aided and unaided decision-making (reflecting whether information about ecosystem services was provided to participants). We showed that when the public is asked to make tree selections without information about those trees, they relied on visually salient and easy to evaluate attributes, e.g., the presence of fruits and flowers. This confirms what others have found in studies of public preferences for urban forests, where the obvious and familiar characteristics of trees play a large role (Baur et al., 2016; Ordóñez et al., 2017). When information was provided, however, significantly more trees with non-visually salient attributes were selected; these attributes were also assigned significantly higher importance ratings when information was provided. These

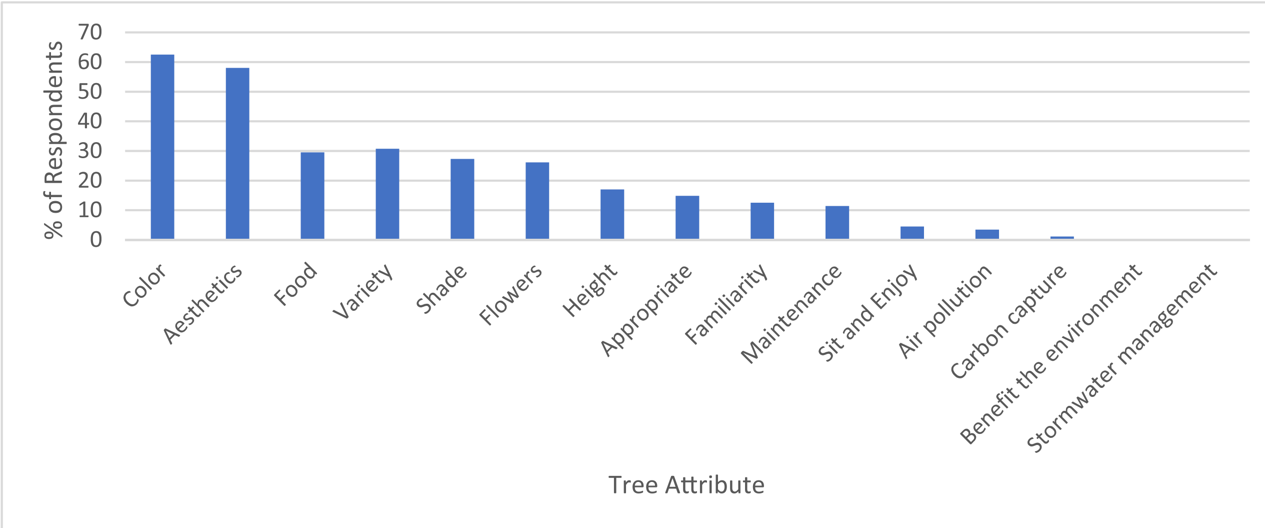

Fig. 8. Percent of respondents mentioning specific tree attributes in response to a prompt asking them to justify their tree choice(s); from the 'No Information' treatment (N = 68).

results echo research suggesting that the public may be less aware of ecosystem functions that cannot be directly observed, and may only include these features in decision-making when prompted (Ordóñez Barona et al., 2016; Peckham et al., 2013; Wissen et al., 2008). Responses to the open-ended question asking participants to justify their tree selections follow this pattern as well. Reference to the visual appearance of trees was most common for those participants who did not receive information (when their selections were unaided). In contrast, environmental benefits, carbon capture, air filtration and stormwater management were consistently and reliably referenced by those who were aided with information about the trees (when these functions were made salient).

When we take a closer look at the tree choices and written justifications from this study, we see some mixed results. There were no significant differences in the number of trees that were selected for stormwater management and shade across the two treatments. It may be that the public has little experience and context within which to consider trees as stormwater infrastructure; it may also be that this is the least well-known of the functions of urban trees (Collins et al., 2019). Stormwater management and flood control may not enjoy this same level of awareness amongst the public, and thus motivated fewer tree selections relative to carbon capture and air filtration. The brief amount of information provided in this study may have been insufficient to influence the salience of this characteristic. Further, this attribute has received little attention in published studies examining public preferences for urban trees, few studies have included this attribute as an option in closed-ended questions (but see Collins et al., 2019) and this feature was mentioned unprompted in only one other study reviewed for this paper. Overall, few trees were selected for stormwater mitigation in this study and this function was rarely included as a justification.

Conversely, we predicted that there would be no difference in the number of trees selected for shade provision nor in the importance rating of this attribute; these hypotheses were supported. We did not see a significant increase in the number of shade trees selected when written information about shade provision was provided. Because this feature is visually salient and easily evaluated, the provision of information may have had a much smaller influence on decision-making (as participants could notice and evaluate shade provision, unaided). However, we note that the selection of trees for shade did not follow the same pattern observed for trees with the other visually salient characteristics included in this study. Instead, the trees selected for shade provision followed a pattern similar to that observed for trees with non-visually salient characteristics. While shade is frequently invoked in studies of urban forests (e.g., Davis and Winter, 2021; Lohr et al., 2004; Su et al., 2022), it may be that this feature was not clearly represented within our virtual 3D landscape. While fruiting and flowering were obvious in the 'virtual trees' used to populate the landscape, the casting of 'virtual' shade may have been too obscure to capture participants' interest (Fig. 2). Further, studies have noted that shade provision and cooling may be most salient when study participants are experiencing hot and sunny weather (Avolio et al., 2015; Ordóñez Barona et al., 2016); data for this study was collected in March 2023. A follow-up study should ensure that shade is clearly illustrated and reflective of that feature's prominence in real life, as well as to include a measure to collect ambient weather conditions at the time a survey is taken (Notaro and Grilli, 2023).

While significantly more fruiting trees were selected in the no-information treatment, there was no significant difference in the importance ratings of this attribute between the two treatments. Though not reported in this paper, fruiting was assessed as an *ecosystem disservice* by some participants in our study (per Kirkpatrick et al., 2013; Lyytimäki and Sipilä, 2009) and thus may have received lower importance ratings upon reflection and in textual responses. A more detailed qualitative analysis of participants' written justifications for their tree selections is forthcoming.

The results of this study provide three novel and practical insights. First, tree preference can change significantly depending on whether information is provided about those trees; in other words, participants in this study constructed their preferences based on what was made salient at the time of judgement (Findlater et al., 2020; Slovic, 1995). For those participants who did not receive any information about the trees, their selections were informed by their preferences for the visual appearance of the trees, including aesthetic judgements. Written justifications, where provided, focused also on these visually salient attributes. For participants provided with a short descriptor of a key ecological function for each tree species, preferences shifted to include trees with those characteristics. These non-visually salient characteristics were also commonly reflected in the written justifications provided by participants in the 'Information' treatment, whereas they were scarcely mentioned when information was not provided.

Second, with increasing interest in including communities in decisions about urban forests, i.e., what to plant, it is important to recognize and account for intuitive decision-making and the construction of preference (Barron et al., 2021; Findlater et al., 2020; Ordóñez Barona et al., 2016). Information needs should be considered in the design of studies; whether administered online or in-person, open-ended survey questions have been shown to result in a different set of urban tree characteristics in comparison to studies that ask participants to rank or rate a pre-determined list (Ordóñez Barona et al., 2022; Ordóñez et al., 2017). In this study, easily evaluated characteristics continued to play a role in decisions; however, when information was provided, ecosystem functions became a significant factor in tree selection for the virtual urban park. Based on the choice of trees in the 'information' condition, participants exhibited implicit preference for trees providing carbon capture and air filtration. When asked to provide a more explicit justification for their tree choices, these attributes were mentioned by participants much more frequently in comparison to those in the 'no information' condition. This pattern of results replicates what is seen in studies using open-ended questions about favoured tree attributes (e.g., where aesthetics plays a large and consistent role) vs closed-ended questions in which we are much more likely to see the inclusion of attributes such as carbon sequestration and air quality improvements (Collins et al., 2019; Ordóñez et al., 2017).

Regardless of the elicitation scenario, the goal should not be to ensure that the public 'thinks' more like an expert but to take steps to thoughtfully include information to support public input into the design and management of urban forests, e.g., to raise awareness of the multiple functions and characteristics of urban trees that are not visually apparent (Collins et al., 2019) and to ensure that communications between planners, scientists and community members are based on that shared understanding. Researchers and practitioners should also be aware of differences in public preferences that may arise as a result of the way preferences are elicited (i.e., open-ended vs closed-ended questions, surveys vs a deliberative co-production process) (Ordóñez Barona et al., 2016; Ordóñez Barona et al., 2022) and when they are elicited (i.e., hot and sunny days). This need is more acute when public input is elicited via online platforms and virtual representations of urban forests. Further, we know that urban tree experts and managers consistently reference carbon sequestration potential, contributions to air quality, and/or mitigation of flooding following heavy rainfall (Barron et al., 2016; Baur et al., 2016); however, these attributes are difficult to recognize without prior knowledge. As has been abundantly illustrated in this and other studies, the public values urban trees based more on visually salient functions, e.g., aesthetics, flowering. These differences additionally reinforce the need to carefully consider the information provided to participants during these engagement efforts. An iterative mix of experimental and deliberative approaches is recommended (Findlater et al., 2020), balancing the careful elicitation of preferences in small groups (per Gregory et al., 2012) with more cost-effective surveys.

Finally, and in line with what has been found in other studies, aesthetics played a large role in participant decision-making, regardless of the treatment to which they were assigned. Even when provided with information about a variety of urban tree functions, aesthetics was a top (if not the top) justification for why a particular tree (or trees) was selected. While not a new result, it is a novel example of the persistent and robust influence of aesthetics on public preferences for urban trees. Further, although it is important to raise awareness of and appreciation for the multifunctionality of urban forests, we must not lose sight of the fact that people are drawn to beautiful landscapes (Gobster et al., 2007). Research suggests that functional landscapes should also be aesthetically pleasing landscapes if they are to enjoy public continued support (Nassauer, 1997; Tribot et al., 2018). Aesthetic considerations should not be discounted in the decision-making and management surrounding urban forests (Brady and Prior, 2020) and can draw people into greenspace stewardship, and appreciation for landscape benefits and services can emerge from that initial engagement (Bell et al., 2020; Li and Nassauer, 2020; Plieninger et al., 2015).

Overall, this research highlights the need for careful consideration of decision support in landscape visualizations, particularly in online settings and when public input is solicited. While intuitive decision-making is a quick and common response in many settings, it is based on information that is easily accessed. The result is biased and suboptimal decision-making. In the context of landscape visualizations, this translates to a focus on visually salient features, at the expense of other ecosystem services. We thus suggest that information support be provided when soliciting public input into urban forest and greenspace planning. Specifically, we recommend including a brief description of the key ecosystem services provided by tree species, particularly when that ecosystem service is not visually salient or is unfamiliar to the public (i.e., carbon sequestration or stormwater regulation). Overall, landscape visualizations present a unique opportunity to experimentally test hypotheses about public preferences for urban trees and greenspaces, and their need for information about hidden/non-visual ecosystem services. These virtual environments also provide opportunities to raise awareness about the multiple functions of urban greenspace, and to support public input into the design and functioning of these spaces.

5. Study Limitations and Future Directions

Decisions related to tree selection, and other landscape elements, are complex and involve a great number of factors, i.e., site characteristics, maintenance requirements, disease resistance (Roman et al., 2021). However, our experimental design allowed us to isolate and test for the role of information, while holding other factors constant (i.e., the setting). We agree with Ribe et al. (2018) that while there is utility in field research about real-world and contextually specific landscape planning processes, there is also value in controlled experimentation to test hypotheses and build broadly applicable theory about public perceptions and preferences. Online virtual 3D representations offer a unique opportunity to gain a deeper and more detailed understanding of public information needs in the context of participatory planning, ecosystem management, and community-based greenspace design. The insights from this controlled experimental work can be used to challenge assumptions about public decision-making and to ensure that these efforts result in high-quality decisions reflective of a diverse set of services and context-specific needs. While aesthetic considerations will continue to dominate decision-making (as a quick heuristic on which to base landscape preferences), there is a need to ensure that urban greenspace design (including tree selection) is multifunctional and climate resilient.

We note that the recruitment strategy for this study was designed to approximate US demographics, however we found that those identifying as Hispanic or Latino were somewhat underrepresented in the final sample. Additionally, this study was restricted to those participants who had access to a desktop computer with an up-to-date operating system; this is reflected in the fact that study participants were slightly more educated than the general US population. However, a key objective for this study was to create a virtual urban greenspace (and accompanying tutorial) to facilitate and support public input into how that space should function and what features should be included. The results from this study build on previous research and were the outcome of a controlled experiment to reveal implicit tree preferences and the influence of information on those choices. Replication of this study in other parts of the US, and utilizing different combinations of tree species, is essential to reinforce the ecological validity of these results.

Future research can use similar experimental settings to compare the information needs of public segments which vary in strength of connection to the landscape context in question (and who may be more motivated to engage). We also see utility in including additional landscape elements in these 3D virtual spaces (i.e., shrubs and forbs, hardscape elements, recreational facilities) and varying the instructions provided to participants (i.e., 'create a design to mitigate the urban heat effect' or to 'facilitate community connections'). Future work will also focus on how best to present information (i.e., comparing text vs graphical displays) to support public input and decision-making. We see great potential for studies which evaluate the effect of participatory virtual 3D landscape planning and design on public knowledge of and appreciation for multifunctional urban greenspaces.

6. Conclusions

With increased interest in engaging the public in decisions about urban forests (and greenspace in general), this study points to the importance of understanding their decision-making processes and information needs. This study illustrates that the public's tree preferences are constructed, where salient characteristics and information priming play a large role in tree selections for urban spaces. This study also reinforces differences in 'expert' and public perceptions of the key functions and characteristics of urban trees, underscoring the need for thoughtful inclusion of information about ecosystem services to support public engagement. This study also points to the importance of aesthetics and access to these spaces to fulfill social needs, e.g., for stress relief, as a respite from the city. An inclusive set of cultural ecosystem services, however, is often not considered in municipal planning and urban forest management, with the potential to diminish sustained public support for these spaces and for urban trees more specifically. Insights into public preference for urban greenspace afforded through the creation of interactive virtual 3D representations of landscapes, and the translation of these preferences into actionable plans for urban parks and greenways, is an important step in rectifying this deficiency.

CRediT authorship contribution statement

Victoria Campbell-Arvai: Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ramiro Serrano Vergel:** Visualization, Software, Methodology, Investigation, Data curation, Conceptualization. **Mark Lindquist:** Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Nathan Fox:** Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Conceptualization. **Derek Van Berkel:** Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128447.

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