Capturing Perceived Everyday Lived Landscapes through Gamification and Active Crowdsourcing

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Capturing Perceived Everyday Lived Landscapes through Gamification and Active Crowdsourcing

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Summary

Landscapes are distinguishable areas of the earth with distinct characters comprised of tangible and intangible dimensions and entities. Interactions between humans and landscapes influence social, physical and mental well-being as well as guide behaviour. Understanding how landscapes are perceived has thus gained traction in sustainable and inclusive policy and decision making processes and public participation is called for. The recognised importance of understanding landscapes from an experiential and perceptual perspective and incorporating public participation in data generation efforts is reflected in overarching conventions, policy guidelines and frameworks including the European Landscape Convention (ELC), the Millennium Ecosystem Assessment (MEA), Natures Contributions to People (NCP) and the Landscape Character Assessment (LCA) framework. Major challenges for these conventions and frameworks are 1) how to collect data on landscape experiences and perceptions from a diverse group of individuals, 2) how to integrate and link physical entities, sensory experiences and intangible dimensions of landscapes and 3) how to identify other potential sources of landscape relevant information.

The abundance of storage space and the accessibility of broadband internet have led to a burgeoning of user generated natural language content. In parallel, various paradigms of exploiting ubiquitous internet access for research purposes have emerged, including crowdsourcing, citizen science, volunteered geographic information and public participation geographic information systems. These low cost approaches have shown great potential in generating large amounts of data, however, they struggle with motivating and retaining participants. Gamification - broadly defined as adding entertaining or playful elements to applications or processes - has been found to increase user motivation and has explicitly been called for in landscape perception and preference research to diversify participant demographics. Meanwhile, natural language has been found to be deeply intertwined with thought and emotion and has been identified as a rich source of semantic data on how landscapes are perceived and experienced. Written texts and the ways in which these can be analysed have gained particular interest. Therefore, the overall goal of this thesis is to develop and implement a gamified crowdsourcing application to collect natural language landscape descriptions and to analyse and explore the

contributions in terms of how landscapes are perceived through sensory experiences and how additional landscape relevant natural language can be identified.

To approach this goal, I first elicit key data and feature requirements to collect landscape relevant information from a heterogeneous audience. Guided by the identified requirements, I develop and implement *Window Expeditions*, a gamified active crowdsourcing platform geared towards collecting natural language descriptions of everyday lived landscapes. The generated corpus of natural language is explored using computational methods and I present and discuss the results in light of who the contributors are, the locations from which participants contribute and salient terms found in English and German. In a further step I annotate a subset of English contributions according to the contained biophysical elements, sensory experiences and cultural ecosystem (dis)services and explore these in terms of how they are linked. Finally, I present a novel approach of using a curated high quality landscape specific dataset to computationally identify similar documents in other corpora using sentence-transformers.

Using the Mechanics, Dynamics and Aesthetics (MDA) framework, the aesthetics of discovery, expression and fellowship were identified as most fitting for an active crowdsourcing platform. In addition, four groups of main dynamics were found, namely general dynamics of user interactions, contribution dynamics, exploration dynamics and moderation dynamics. The application was gamified by introducing points and leader boards and the platform was implemented in German and English (with French being added at a later point) to collect landscape descriptions in multiple languages. Demographic information was collected about the users including their year of birth, their gender, if they were at home whilst contributing and what languages users believed to be fluent in.

Between August 2020 and February 2022 a total of 638 contributions were uploaded by 88 registered users who contributed 170 descriptions and 426 anonymous users who contributed 468 descriptions. Most participants contributed once ($n = 480$) and a small number of users ($n = 4$) contributed 12 to 25 descriptions each. Millennials were most likely to participate reflected in the participants' median (1990) and mean (1986) year of birth. Most contributions were uploaded by female participants ($n = 279$) with slightly less from male participants ($n = 256$) and a small number from non-binary individuals ($n = 5$) or other ($n = 1$) as well as about 10% choosing not to report their gender ($n = 51$). Most contributions were uploaded using the English version ($n = 426$), followed by German ($n = 181$) and French ($n = 31$). The majority of participants reported being fluent in English ($n = 473$), followed by German ($n = 209$), French ($n = 60$), Spanish ($n = 42$) and Italian ($n = 15$). A significant difference in landcover types was found between people reporting being at home ($n = 466$) who were more likely to be in urban environments than users reporting not being at home ($n = 172$) who were more likely to contribute from areas of herbaceous vegetation.

Terms describing salient elements of everyday lived environments such as "*tree*", "*house*", "*garden*" and "*street*", as well as weather related phenomena and colours were found frequently in both English and German contributions in the generated corpus. Further, terms related to space, time and people were found significantly more frequently in the generated corpus compared to general natural language and representative landscape image descriptions highlighting the importance of spatial features as well as people and the times at which these were observed. Notably, descriptions referring to trees and birds were frequently found in the contributed texts, underlining their saliency in everyday lived landscapes.

The results show biophyiscal terms related to vegetation ($n = 556$) and the built environment ($n = 468$) as well as weather related terms ($n = 452$) to be most prominent. Further, contributions referencing visual ($n = 186$) and auditory ($n = 96$) sensory experiences were found most often with positive sensory experiences being most common ($n = 168$) followed by neutral ($n = 86$) and negative ($n = 68$). In regards to the intangible dimensions captured in the contributed landscape descriptions, recreation ($n = 68$) was found most often followed by heritage ($n = 36$), identity ($n = 26$) and tranquillity ($n = 23$). Through linking biophysical elements, sensory experiences and cultural ecosystem (dis)services, the results show that the biophysical category of *animals* appears often with the sensory experience of *smell/taste* and the biophysical category of *moving objects* appears more than expected with the sensory experience of *sound*. Further, the results show the cultural ecosystem service of *inspiration* to often appear with the biophysical category of *natural features* and *tranquillity* with *weather*.

Using a curated subcorpus of English natural language landscape descriptions ($n = 428$) collected with *Window Expeditions*, similar documents in other collections were identified. Through translating documents to vectors by means of sentence-transformers and calculating cosine similarity scores, a total of 6075 to 8172 documents were identified to be similar to contributions to *Window Expeditions*, depending on if the initial dataset was prefiltered for biophysical noun lemmas (a list of biophysical landscape elements derived from the *Window Expeditions* corpus) and Craik's list adjectives (a list of common adjectives used to describe landscapes). Latent Dirichlet allocation topic modelling, a clustering approach which is commonly used to identify overarching topics or themes in collections of natural language, shows four distinct clusters in both *Window Expeditions* as well as in the corpus of identified similar documents, namely *urban and residential*, *rural and natural*, *autumn and colours* and *snow and weather*.

Overall, the results presented in this thesis provide further evidence to work that natural language is a rich source of landscape specific information, capturing underlying semantics of a multitude of referenced landscape dimensions. In particular, this thesis demonstrates that computationally aided approaches to analysing and exploring landscape relevant textual data can give detailed insights into salient features of landscapes and how individuals perceive and experience these. Especially when complemented by human annotation, natural language landscape descriptions are a welcome source of data about a landscape's biophysical elements, individual sensory experiences in landscapes and the perceived cultural ecosystem (dis)services.

The findings of this thesis are accompanied by various limitations, chief amongst which are the possibilities of users to falsify their locations, the rather small amount of data that was collected through *Window Expeditions* and the Eurocentric definitions and approaches common in landscape perception research. The former two limitations can be addressed through implementational reiterations and promotional efforts, whereas the latter limitation calls for further consideration of the socio-culturally induced construction of landscape perception research and a rethinking of holistic approaches, especially in multicultural participatory contexts.

The work presented in this thesis shows great potential in complementing landscape perception research with gamified methods of data generation. Active crowdsourcing can be a cost efficient and scalable approach of generating much needed data from a diverse audience. Exploring landscape relevant natural language with both quantitative and qualitative methods from various disciplines including geographic information science, linguistics and machine learning can lead to new insights into landscape perception, sensory landscape experiences and how these are expressed.

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Publications

Following is a list of publications I have been involved in as part of my academic journey:

Baer, M. F. & Purves, R. S. **Window Expeditions: A playful approach to crowd-sourcing natural language descriptions of everyday lived landscapes.** Applied Geography. Volume 148, November 2022. https://doi.org/10.1016/j.apgeog.2022.102802

Baer, M. F. & Tregel, T. & Laato, S. & Söbke, H. **Virtually (re)constructed reality: the representation of physical space in commercial location-based games.** Academic Mindtrek 2022: 25th International Academic Mindtrek conference, November 2022. https://doi.org/10.1145/3569219.3569339

Hartmann, M. C. & Koblet, O. & Baer, M. F. & Purves, R. S. **Automated motif identification: Analysing Flickr images to identify popular viewpoints in Europe's protected areas.** Journal of Outdoor Recreation and Tourism. Volume 37, March 2022. https://doi.org/10.1016/j.jort.2021.100479

Thibault, M. & Baer, M. F. **Urban Gamification during Lockdown and Social Isolation – From the Teddy Bear Challenge to Window Expeditions.** GamiFIN21. 2021. http://ceur-ws.org/Vol-2883/paper14.pdf

Wartmann, F. M. & Baer, M. F. & Hegetschweiler, K. T. & Fischer, C. & Hunziker, M. & Purves, R. S. **Assessing the potential of social media for estimating recreational use of urban and peri-urban forests.** Urban Forestry & Urban Greening. 2021. https://doi.org/10.1016/j.ufug.2021.127261

Baer, M. F. & Wartmann, F. M. & Purves, R. S. **StarBorn: Towards making in-situ land cover data generation fun with a location-based game.** Transaction in GIS. 2019; 00: 1–21. https://doi.org/10.1111/tgis.12543

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1 Introduction

> *If I wanted you, the reader, to begin to understand about landscape, I would not start with the work of anthropologists, or geographers, or academics of any sort. I would begin with novelists and poets...*
>
> — **Barbara Bender**
>
> (Author)

Landscapes, the fickle areas in which our lives unfold, have inspired beautiful paintings and famous poems as well as myriad avenues of academic research. Their unique characters nurturing our curiosity, influencing our perception and guiding our behaviour. In other words, landscapes are the environments we live in, experience, appreciate and interact with (European Landscape Convention, 2000), affecting our mental, social and physical well-being (Abraham et al., 2010; Thompson, 2011; Menatti and Da Rocha, 2016). These environments are by no means mundane homogeneous areas, but patchworks of various material and immaterial properties and dimensions (Hermann et al., 2011) which are summarised as a landscape's character (distinct elements or characteristics), ecosystem (dis)services (services and deterrents that influence our well-being) and affordances (possibilities of action guiding behaviour) (Brabyn, 2009; Heft, 2010; Tudor, 2014; Shapiro and Báldi, 2014; Costanza et al., 2017; Raymond et al., 2017; Heras-Escribano and Pinedo-García, 2018). Data on landscape character, ecosystem (dis)services and affordances not only capture a landscape's current state, but are vital in guiding informed decisions and working towards sustainable policies and inclusive planning (Scott, 2003; Antrop, 2005; Tudor, 2014; Bubalo et al., 2019). The demand for data on how people interact with multifunctional landscapes and how these influence well-being has further increased in light of the Covid-19 pandemic, in the course of which many local landscapes experienced an uptake in visitations as people sought solace in nature (Morse et al., 2020).

During the past four decades, landscape related research has seen the introduction of various conventions and frameworks, most notably the European Landscape Convention (ELC), the Millennium Ecosystem Assessment (MEA), Nature's Contributions to People (NCP) and the Landscape Character Assessment (LCA) framework

(European Landscape Convention, 2000; Millennium Ecosystem Assessment, 2005; Tudor, 2014; Díaz et al., 2018). These conventions and frameworks overlap in acknowledging the value of public participation in landscape research and generally agreeing that "today, many policy levels, interest groups and scientific disciplines are involved in the landscape, making it a complex multi-layered business, with inter- and trans-disciplinary processes that sometimes interact, sometimes compete and still too rarely give consistent results" (Antrop, 2013, p. 19). Anthropologists, geographers and related academic fields have striven to better understand landscapes and while a wide range of sensors are capable of capturing environmental variables related to the physical properties of landscapes at scale (cf. Lambin et al., 2001; Swetnam et al., 2017) capturing information about how landscapes are perceived by individuals remains much more challenging. The nature of this challenge is nicely summarised by Barbara Bender (Bender, 2006, pp. 303) (see introductory citation above) who points to the richness of language as a way of conveying information about landscapes. By identifying writers as a rich potential source of landscape relevant information, Bender implicitly embraces the subjectivity of such writing about landscapes as a route to understanding. In other words, given a collection of texts about landscapes, we can start to explore how people, languages and landscapes are entangled.

Our personal knowledge about landscapes, what these offer and how these shape our lives, is the sum of our own experiences combined with the wisdom encoded in natural spoken or written language and still or moving images. Written and spoken natural language is our primary form of expression and a tool for conveying knowledge and experiences (Pinker, 2003) about ourselves and our surroundings. Linguistic relativity further postulates that language and thought are intimately related, suggesting that the wide variety of languages, spoken in an equally wide diversity of landscapes, offers a looking glass through which we can explore and compare how individuals perceive and value various landscapes (cf. Brabyn and Mark, 2011; Antrop, 2013; Drexler, 2013; Bruns et al., 2015; Majid et al., 2018; Fairclough et al., 2018). For example, from uncovering different notions of what a forest might be (Burenhult et al., 2017; Gupta and Gahegan, 2020), over exploring the recreational potential of landscapes (Wartmann et al., 2021a), to understanding how landscapes are experienced as bodies of giant mythical beings (Burenhult, 2004). These differences can be viewed through the lens of the semiotic triangle - a model of how linguistic representations such as a term or symbol relates to a real world entity or object (Ogden and Richards, 1923). The semiotic triangle consists of three dimensions: internal representations (e.g. notion of what a tree is), referents (e.g. the real-world tree) and symbols used to refer to referents (e.g. the term "tree"). These dimensions can vary greatly between individuals depending on their socio-cultural background and thus, the semiotic triangle serves as an ideal starting point of disentangling individual perceptions of landscapes.

Differences not only emerge between different cultures and languages, but also between individuals of similar socio-cultural backgrounds with varying levels of expertise. Landscape research traditionally favoured expert opinions over including the general public (Lowenthal and Prince, 1965; Swanwick, 2009) leading to a dichotomy between laypersons and experts in landscape perception research. The general public commonly associates the term landscape with the countryside and as strongly related to nature or being something natural (Swanwick, 2009) which has been observed over multiple languages (Bruns et al., 2015). This anecdotal impression of what landscapes encompass is in need of an overhaul, especially seeing that "ordinary people living ordinary lives inhabit meaningful spaces; in globalized urban environments, these spaces are vernacular landscapes" (Krase and Shortell, 2011, p. 371). Experts in contemporary landscape research on the other hand have included these vernacular landscapes in their broader definition and combine quantitative and qualitative approaches towards more holistic analyses of landscapes (Swanwick, 2009; Bruns et al., 2015). These vernacular landscapes have also been referred to as everyday living environments (Plieninger et al., 2014) which seems appropriate seeing many of us spend most our time in such landscapes. I term these vernacular landscapes and everyday living environments as *everyday lived landscapes* in this thesis as an attempt at redirecting the scientific research focus to salient features of everyday life in favour of idealised landscapes of high aesthetic value (cf. Antrop, 2013).

The importance of acknowledging potential differences in what lay people and experts believe landscapes encompass calls for a naive geography (Egenhofer and Mark, 1995; Brabyn, 2009) of landscapes. Naive geography "captures and reflects the way people think and reason about geographic space and time, both consciously and subconsciously" (Egenhofer and Mark, 1995, p. 6). In other words, people may have varying (sometimes distorted) views of spatial-temporal phenomena which cannot always be reflected in numeric metrics. This reminds us of Barbara Bender's quote advocating for a more cultural and artistic approach to understanding landscapes and is in line with the aforementioned semiotic triangle in that internal representations, referents and symbols can vary within and between socio-cultural groups. Collecting and analysing natural language can advance our understanding of common people's perceptions of everyday lived landscapes and how and why individuals perceive certain landscape dimensions over others. The question thus emerges: how can we collect such natural language landscape descriptions about everyday lived landscapes that capture the rich diversity found within and between cultures and socio-demographic groups and what added benefit does such a dataset provide?

Traditionally, approaches of describing and classifying landscapes were divided into two schools of thought. Natural sciences categorised landscapes according to their biophysical components and the arts and humanities focused on the aesthetic, socio-cultural and perceptual dimensions of landscapes (Simensen et al., 2018). The gradual merging of these schools of thought led to a paradigm shift from top-down approaches, mostly incorporating expert knowledge, towards more bottom-up approaches, acknowledging non-expert users' contributions (Swanwick, 2009) and capturing local knowledge. Although traditional methods such as expert opinions (Krueger et al., 2012; Swanwick, 2009) and surveys (Bromley, 1981; Ruff and Maddison, 1994) have proven to generate high quality data for scientific research, they are often accompanied by major limitations including financial or time restrictions. The participatory turn in many academic disciplines, manifested as an increase in publications incorporating some form of participatory data generation (cf. Goodchild, 2007; See et al., 2016), has trickled down into landscape perception and preference research and has led to various complementary landscape data generation efforts. Contemporary approaches include participatory methods such as free-listing exercises (Wartmann and Purves, 2018; Wartmann et al., 2018), internet surveys (Wherrett, 2000) and participatory mapping (Brown and Fagerholm, 2015; Brown, 2015) as well as tapping into an (imagined) abundance of social media data (Bubalo et al., 2019). However, we must keep in mind that even though there is an unfathomable amount of user generated social media content stored on uncountable servers spread across the world, only a small portion is available for academic use, and even less related to landscape.

One widely adopted branch of participatory data generation is crowdsourcing, which has seen a surge of popularity with ubiquitous access to broadband internet. Crowdsourcing is defined as "a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task" (Estellés-Arolas and González-Ladrón-De-Guevara, 2012, p. 9). In other words, crowdsourcing refers to the practice of voluntarily and collaboratively working on a task or project in an online setting. Another definition divides crowdsourcing into two broad categories: active crowdsourcing (where participants are informed of the task and actively contribute data towards a given question or topic in line with the definition above) and passive crowdsourcing (where users contribute data without being aware of the scientific use case such as in social media) (See et al., 2016; Bubalo et al., 2019). Crowdsourcing, both active and passive, has seen substantial growth over the past decade and is increasingly incorporated in various academic disciplines.

However, motivating people to participate in crowdsourcing projects remains challenging. Thus, many efforts attempt to augment people's intrinsic and extrinsic motivation to increase participation and retention (cf. Morschheuser et al., 2016; Fritz et al., 2017). Intrinsic motivation refers to individuals being motivated through “inherent satisfactions rather than for some separable consequence” (Ryan and Deci, 2000, p. 56) such as self-education, challenge and fun, whereas extrinsic motivation “pertains whenever an activity is done in order to attain some separable outcome” (Ryan and Deci, 2000, p. 60) such as monetary compensations or virtual badges. One promising approach of not only increasing intrinsic and extrinsic motivation but also “engaging a younger audience” (Bubalo et al., 2019, p. 109) is gamification: incorporating entertaining or playful elements into an existing process (Hamari et al., 2014; Morschheuser et al., 2016). Well known examples of gamified crowdsourcing applications in geographic information generation are Pokémon GO and Ingress (Colley et al., 2017; Laato et al., 2019a), two of the most popular location based games developed by Niantic[1] and played by hundreds of millions of people worldwide (cf. Laato et al., 2019a; Baer et al., 2022). Mentioned applications motivated an unprecedented number of users to contribute cultural points of interest by uploading natural language descriptions and images and thus arguably belong to the most successful spatial crowdsourcing campaigns. These examples go to show the potential of gamifying crowdsourcing tasks, however, questions of how to integrate game elements into a rigorous scientific approach and how to ensure a balance between gamification and crowdsourcing task complexity are in need of further investigation. Of particular interest is how gamification can motivate the collection of high quality landscape relevant information, for example in-situ natural language landscape descriptions.

Natural language has been recognised as a rich source of landscape relevant data and offers insights into comparing varying conceptualisations of landscapes, over identifying salient physical and intangible dimensions, to capturing various senses involved in experiencing landscapes and the emotional responses thereof (Fish et al., 2016; Majid and Levinson, 2011; Mark and Turk, 2017). User generated natural language, in combination with large collections of digitised text sources such as books and articles (Michel et al., 2011), offer a vast underlying dataset to investigate landscapes. Recent studies have used natural language as underlying sources to compare landscapes through spatial folksonomies (Brabyn and Mark, 2011) using digitised alpine club yearbooks (Derungs and Purves, 2016), to model recreational use of landscapes from social media texts (Wartmann et al., 2021a), to explore perceived sounds and tranquillity in landscapes using online image descriptions and lists of terms (Koblet and Purves, 2020; Wartmann et al., 2021b) and to extract cultural ecosystem services from short-stories (Bieling, 2014) to name a few. This list is in no way extensive, however it goes to show the wide variety of topics which can be approached through different forms of natural language. Most sources of textual data used in landscape perception research to date are not explicitly landscape related and identifying relevant documents in large corpora remains challenging.

[1] www.nianticlabs.com (accessed: 20.08.2022)

Successfully collating a gold standard of natural language landscape descriptions could increase the proficiency of identifying landscape relevant documents. This calls for active approaches of generating natural language landscape descriptions and a thorough inspection of the characteristics of the generated documents and how these compare to other sources of textual data in terms of landscape relevance and the captured dimensions.

The introduced context of this thesis and the identified points in need of further investigation provide the starting point of this thesis and build the foundation of the overarching research question giving the scope of this thesis:

How can everyday lived landscape perceptions be collected, extracted and analysed from natural language descriptions of everyday lived landscapes actively crowdsourced through a gamified application?

The following thesis is divided into four main parts, aiming to address this overarching research question. The first part introduces the overarching theme and topic of this thesis and how the research is embedded in a wider scientific context (Chapter 1), before presenting relevant state of the art literature (Chapter 2) as well as the identified research gaps and detailed research questions. In the second part of this thesis an overview of how gamification has been incorporated in geographic information science will be given followed by introducing two applications - *StarBorn* and *Percy's World* - that were developed to further investigate the potential of gamification in landscape data generation (Chapter 3). The knowledge gleaned from reviewing the gamification literature and the lessons learned from the two presented platforms is then used to guide the implementation of *Window Expeditions*, an active crowdsourcing platform to collect natural language landscape descriptions. The third part of this thesis presents the implementation of *Window Expeditions* (Chapter 4) as well as the methods used to analyse the generated data (Chapter 5). Further, I present the results of computationally analysing the contributions to *Window Expeditions* as well as how biophysical elements, sensory experiences and cultural ecosystem (dis)services were explored (Chapter 6) and how natural language processing and machine learning techniques were applied to identify similar documents in other corpora (Chapter 7). Lastly, the fourth part of this thesis synthesises the findings of the individual chapters and discusses these in relation to the literature (Chapter 8) before summarising the thesis in a conclusion (Chapter 9).

2 Background

> *Who controls the past controls the future: who controls the present controls the past.*
>
> — **George Orwell**
>
> (Author)

Inquiries into landscapes have had a long and dynamic past. In the past four years, I have consolidated a wide range of literature of which I present relevant findings in this chapter. I first delve into the history of the term *landscape*, how the term has evolved and introduce a widely accepted definition. I then shed light on the topics of perception and how landscapes are explored in contemporary landscape perception research tying together sensory experiences, cultural ecosystem (dis)services and affordances of landscapes. Further, I introduce gamification and natural language processing as important implementational and analytical approaches for this thesis. Finally, I conclude with a short summary of the identified research gaps as well as a number of detailed research questions which this thesis aims to answer.

2.1 A brief history of landscapes

Landscapes, and how humans perceive these, have fascinated laypeople and scientists for centuries. From landscape paintings and vivid landscape descriptions in poems and books (Berr and Schenk, 2019) over the development of various landscape characterisation methods (Fairclough et al., 2018) up to investigating how landscapes impact human well-being (Abraham et al., 2010; Thompson, 2011). But what are landscapes? How has the term *landscape* evolved and what are the implications for modern landscape perception and preference research?

2.1.1 Etymology

The term landscape was first documented as the Old High German term *Lantscaf* in the early 9th century (Gruenter, 1975) and was mostly used to refer to a settlement area or political region (Berr and Schenk, 2019). The Anglo-Saxon term *lantscipe* was similarly used to denote a region, tract of land, country or district, however this term was found to have died out (Olwig, 1996). In the 16th century the Dutch term *lantscap* was introduced into the English language as *landscape*, replacing the term *lantscipe*, and referring to the art form of landscape painting (Hard, 1970).

This (re)introduction of the term resulted in a shift toward a more aesthetic connotation and the term continued to change and evolve. A first more holistic definition of *Landschaft* (translation: landscape) is attributed to Alexander von Humboldt as the „Totalcharakter einer Erdgegend" (translation: "total character of an area of the earth") (Antrop, 2013, p. 14) emphasising a landscape's character. Even though Humboldt's notion of *landscape character* addressed the more natural attributes of a given environment, the fundamental idea of landscapes having a character entails a myriad of new avenues of exploring and comparing these, thus marking the beginning of modern landscape concepts.

The idea of landscapes having a distinct character and encompassing varying scales has persevered and can be found in common contemporary landscape concepts (cf. Tudor, 2014; Fairclough et al., 2018). Landscapes can be bounded by either identifiable bona fide borders (e.g. the edge of a forest) or socially constructed fiat borders (e.g. a downtown urban area) (Smith and Varzi, 2000) making landscapes distinct areas of cohesive character. Humboldt's original definition has inspired an increasing number of ever detailed definitions with a focus ranging from ecological aspects (Farina, 2008) to human interactions (European Landscape Convention, 2000).

> The term *landscape* has evolved from denoting a region, over visually pleasing environments to areas of distinct character.

2.1.2 Towards a landscape definition

Especially the role of humans and human perception has become increasingly prominent in the definitions of landscapes. This is highlighted in the widely used and commonly accepted contemporary landscape definition set forth by the European Landscape Convention (ELC) in which a landscape is defined as:

> "An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (European Landscape Convention, 2000, p. 2).

This definition encompasses six important aspects crucial for landscape perception and preference research:

An area...

Landscapes are areas of varying scales and are commonly nameable spatial units (cf. Bruns et al., 2015)

...as perceived...

How landscapes are perceived depends on individual as well as group factors such as socio-cultural or demographic backgrounds (cf. Antrop, 2013; Drexler, 2013; Bruns et al., 2015; Majid et al., 2018; Fairclough et al., 2018)

...by people...

The views of all people should be included when studying landscapes and not merely the views of an academic or political elite (cf. Egenhofer and Mark, 1995; Jones, 2007; Swanwick, 2009)

...whose character...

Landscapes have a specific character which can be discovered, described and analysed (cf. Antrop, 2013; Bruns et al., 2015)

...is the result of the action and interaction...

landscapes are valued, shaped and used by humans through actions and interactions (cf. Gibson, 1986; Heft, 2010; Bruns et al., 2015)

...of natural and/or human factors.

Landscapes encompass both cultural and natural elements including the interactions thereof and with humans (cf. Herzog et al., 2000)

The European Landscape Convention's notion of landscape forefronts the importance of human perception and the interactions between humans and nature. However, the translation of the term into other languages is accompanied by various limitations. Even though the term is translated (e.g. French: "paysage" or German: "Landschaft"), the translations are often accompanied by different schools of thought and underlying concepts (cf. Olwig, 1996; Antrop, 2005; Fairclough et al., 2018; Putten et al., 2020). Not only is this a result of different research cultures, but also due to language being "[. . .] fundamentally entangled with culture, identity, intellectual discourse and ideology or emotion" (Fairclough et al., 2018, p. 15).

Meanings of the term landscape and whether or not the concept exists is deeply rooted within a respective society. This includes varying denotations of landscape terms in different languages up to fundamentally different perceptions of landscape features and the possibilities of action there-in (cf. Gibson, 1986; Burenhult and Levinson, 2008; Gehring and Kohsaka, 2007; Smith and Fiore, 2010; Mark et al., 2011; Comber et al., 2016). Thus, all encompassing approaches to describing and characterising landscapes are called for covering all relevant dimensions ranging from natural to social and from individual to cultural. In the following I present and discuss the most common contemporary approaches.

> The widely adopted definition of landscape moves away from landscapes as conglomerates of biophysical features towards emphasising the importance of perception and the interactions between people and their surroundings in a given environment

2.2 Describing landscapes

Before the rise of character-based approaches, landscape value was commonly reduced to biophysical properties or aesthetic appeal and particular landscapes were regarded as valuable to encourage protection thereof (McCauley, 2006; Swanwick, 2009; Sarlöv Herlin, 2016; Costanza et al., 2017). The end of the 20th century saw a paradigm shift in the natural sciences from landscapes as natural or aesthetic entities, towards landscapes being intertwined with society and culture, paving the way for modern landscape assessment approaches (Antrop, 2005; Fairclough et al., 2018; Fairclough et al., 2018). Research practises began to move away from reducing landscapes to mere numbers and statistics and started favouring a more subjective approach by regarding landscapes as a whole and considering their experiential value (cf. Swanwick et al., 2007).

Many approaches and methods of assessing a landscape's character started emerging between the late 1980s and the mid 1990s (cf. Fairclough et al., 2018) of which, in the following, two dominant and well established approaches are introduced, namely *Ecosystem Services (ES)* and *Landscape Character Assessment (LCA)*. These two approaches find their origins in different disciplines with ecosystem services coming from natural sciences and focusing on natural attributes, whereas landscape character assessments incorporate theories from humanities, fore-fronting the experiential and perceptual dimensions of landscapes. This thesis treats these two approaches as complimentary in hopes of a more holistic exploration of everyday lived landscapes.

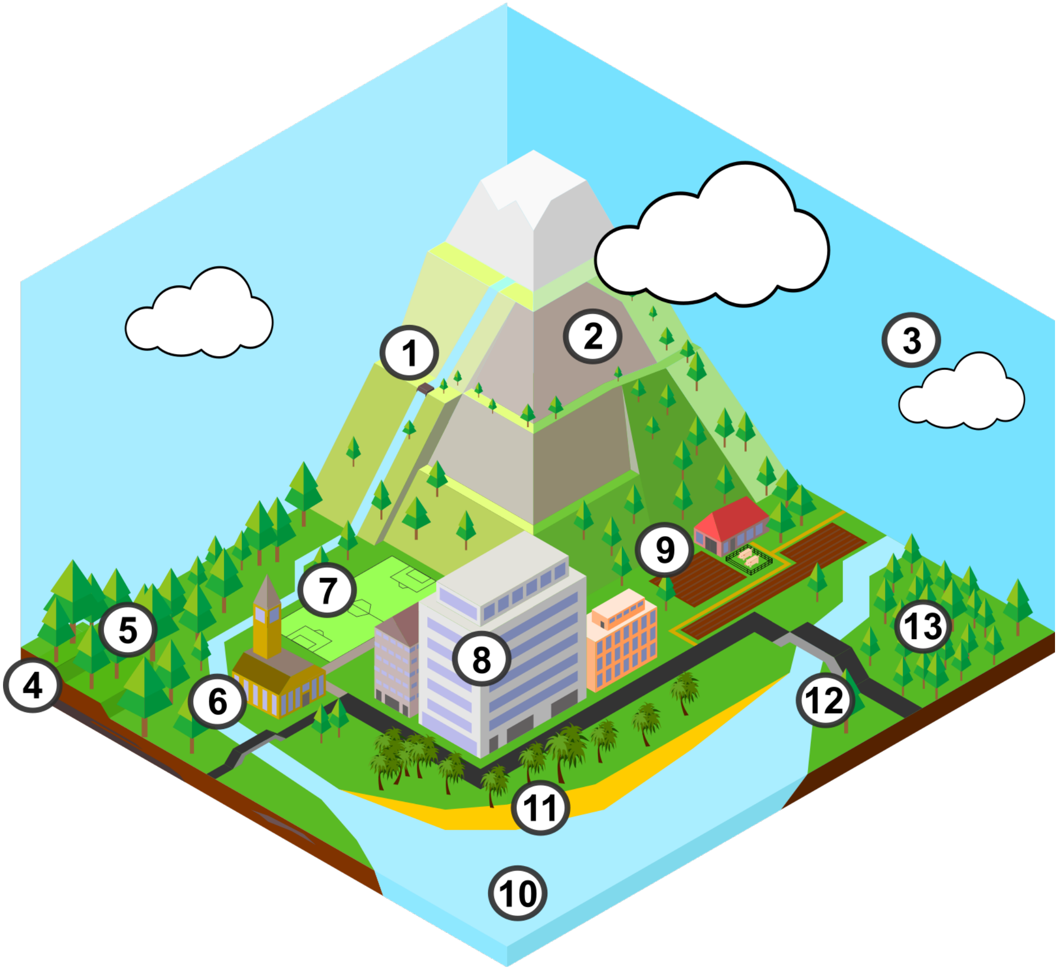


Figure 2.1: Isometric example of a landscape to visualise Ecosystem Services and Landscape Character dimensions. The figure features: a regulated mountain stream (1), a mountain cliff (2), clouds and the atmosphere (3), underground geological structures (4), an elevated forested area (5), a representative religious structure (6), a football field (7), an urban area (8), an agricultural area (9), a large body of water (10), a beach (11), a bridge and dam (12) and a riverside forest (13)

2.2.1 Ecosystem services (ES)

A widely used approach of understanding landscapes is through Ecosystem Services (ES). Ecosystem Services are defined as "the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing" (Costanza et al., 2017, p. 3) or more broadly as "natural capital" (Shapiro and Báldi, 2014). These are divided into four overarching services: provisioning services, regulating services, cultural services and supporting services (cf. Table 2.1) (Daily, 2013; Millennium Ecosystem Assessment, 2005; Costanza et al., 2017). The ecosystem services approach is commonly applied to quantify the value of landscapes or parts thereof in monetary terms (cf. Costanza et al., 1997; Daily, 2013) to allow for varying landscapes to be compared (Costanza et al., 2017). Provisioning services such as *food production* and *water provisioning* as well as the specific cultural ecosystem service *tourism and recreation* are the most common services to be translated into monetary values (Boerema et al., 2017). For regulating services such as *water purification* and *soil retention* on the other hand, the monetary values are rarely estimated (Boerema et al., 2017).

Overarching ES	Ecosystem examples and references to Figure 2.1
Provisioning services	food (9) and building materials (13)
Regulating services	flood or drought mitigation (1, 10 - 12)
Cultural services	identity (2), tranquility (5, 11, 13), recreation (2, 7, 10), heritage (6, 8), inspiration (2, 5, 11), spiritual and religious values (6)
Supporting services	soil formation (2) and nutrient cycling (4)

Table 2.1: Table of overarching Ecosystem Services and respective examples. The numbers in brackets refer to the visual example(s) in Figure 2.1 where respective services may be found

The approaches used to gauge the monetary value of specific ecosystem services can vary greatly between individual studies, highlighting the complexity of condensing whole ecosystems and their services to a monetary value (Boerema et al., 2017). One common approach is to elicit how much individuals would pay for a given service. The estimated value, or the willingness of individuals to pay, is commonly elicited through revealed and stated preferences (Adamowicz et al., 1994; Haab and McConnell, 2002). Revealed preferences revolve around "analyzing individuals' choices in real-world settings and inferring value from those observed choices" (Costanza et al., 2017, p. 9), whereas stated preferences "rely on individuals' responses to hypothetical scenarios involving ecosystem services" (Costanza et al., 2017, p. 9). In other words, revealed preferences are revealed through proxies based on real world choices and stated preferences are explicitly stated answers to direct questions of value and preference in a scenario setting.

The ecosystem services approach has enjoyed increasing popularity within the scientific community (Costanza et al., 2017), however, the approach has been criticised for only focusing on the benefits or positive aspects of landscapes whilst disregarding negative or threatening properties (McCauley, 2006; Lyytimäki and Sipilä, 2009; Dunn, 2010). Thus, complementing ecosystem services approaches with ecosystem dis-services (including the negative effects of landscapes on human well-being) has been called for (Shapiro and Báldi, 2014). In the remainder of this thesis the terms *ecosystem services* and *cultural ecosystem services* take positive as well as negative aspects into account and are thus considered as synonyms of *ecosystem (dis)services* and *cultural ecosystem (dis)services*.

Recently, exploring questions regarding intangible dimensions of landscapes such as landscape preferences (Larsen and Harlan, 2006; Zanten et al., 2014; Bubalo et al., 2019) and the recreational value of landscapes (Scholte et al., 2018; Biedenweg et al., 2019) have become important (Milcu et al., 2013). These intangible dimensions of landscapes are commonly investigated through the lens of cultural ecosystem services (CES) (cf. Bieling, 2014; Wartmann and Purves, 2018; Fagerholm et al., 2020). Cultural ecosystem services are generally divided into the subdimensions of recreation and (eco)tourism, aesthetics, spiritual and religious values including ethical dimensions, cultural heritage, inspiration, identity and tranquility (cf. Milcu et al., 2013; Bieling, 2014; Fish et al., 2016; Fagerholm et al., 2020). Of these, recreation, aesthetic and spiritual and religious dimensions have received most attention in the scientific literature (Milcu et al., 2013). In addition, tranquility has been found to be an important and valued property of landscapes (cf. Wartmann et al., 2018; Wartmann et al., 2019; Fagerholm et al., 2020; Koblet and Purves, 2020). The ecosystem services approach has resulted in a large increase in research on ecosystems as well as landscapes in general and has encouraged numerous conservation efforts. However, the critique of assigning monetary values to landscapes and only focusing on the benefits and not the detriments of landscapes on human well-being calls for complementary approaches.

> The ecosystem services (ES) approach focuses on what environments provide as provisioning, regulating, supporting and cultural services and commonly aims at making landscapes comparable by estimating an areas monetary value.

2.2.2 Landscape character assessment (LCA)

A parallel development can be found in the Landscape Character Assessment (LCA) framework (Tudor, 2014), which has its roots in England and Scotland towards the late 1980s (Fairclough et al., 2018). The framework is fully formalised and widely used today. In 2002 the best practice approach "Landscape Character Assessment Guidance for England and Scotland" (Swanwick, 2002) was published, firmly establishing the term *Landscape Character Assessment* and paving the way for the widespread adoption of landscape characterisation (cf. Fairclough et al., 2018). A decade later, the guidance was revised and built upon as "An Approach to Landscape Character Assessment" (Tudor, 2014).

This new guidance remains one of the most influential works in landscape character assessment in many countries and research disciplines (cf. Fairclough et al., 2018). The authors define landscape character as "a distinct and recognisable pattern of elements, or characteristics, in the landscape that make one landscape different from another, rather than better or worse" (Tudor, 2014, p. 8). This includes an important difference to the Ecosystem Services approach: one landscape is not better or worse than another and environments are not compressed to a single monetary value (Brabyn, 2009). Conducting a landscape character assessment thus revolves around identifying and explaining a landscape's character, the unique combination of elements and characteristics found within an area (cf. Example 2.1). As a result, a set of dimensions were defined to reduce complexity and allow for the comparison of different landscapes (cf. Figure 2.2).

Example 2.1
An excerpt of the Landscape Character Assessment of Cambridge City conducted by the Cambridge City Council:
"The built heritage and associated spaces, planned landscape, open spaces, woodland, trees and wildlife habitats, agricultural hinterland, the river and the recreational use and amenity value of the area in and around Cambridge are highly valued. Where identified as Defining Character they are regarded as so closely associated with Cambridge and what makes it distinctive, they are irreplaceable and should be regarded as 'sacrosanct'. In this context it means important elements and features which make up the singular character of the City and its setting should be conserved. There should generally be a presumption against development which does not respect existing character. Any small-scale new development should take account of, and preserve, the essence of the character and qualities of the area, or improve upon them." (Cambridge City Council, 2003)

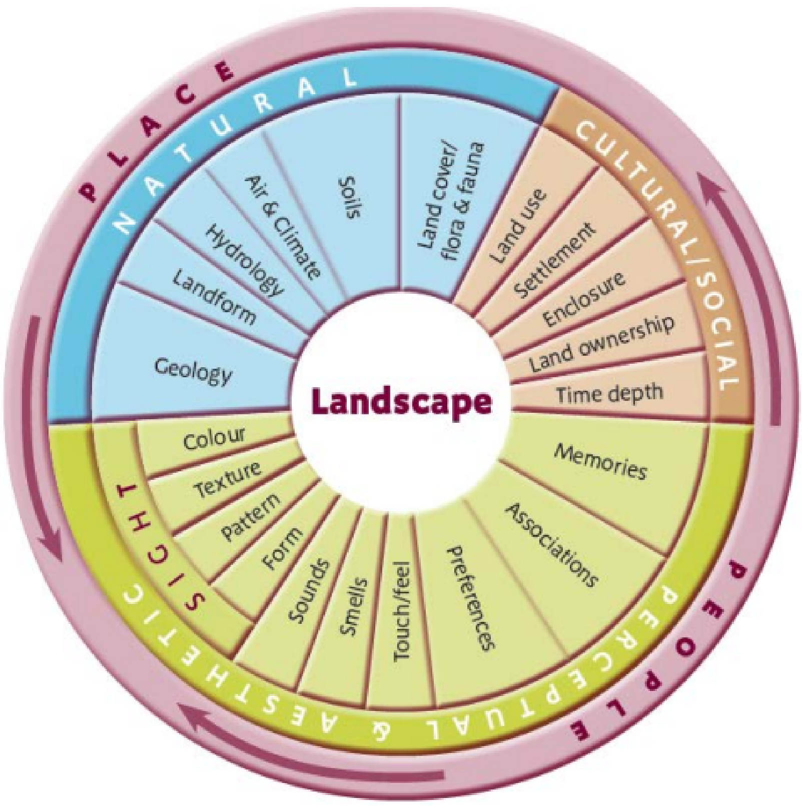


Figure 2.2: Landscape Dimensions in the Landscape Character Assessment Framework (Tudor, 2014). Licensed under the Open Government Licence v3.0 - www.nationalarchives.gov.uk/doc/open-government-licence/version/3/ (accessed: 11.11.2022)

The dimensions are composed of three hierarchical levels (cf. Figure 2.2). The top-level categories are place and people presented as a gradient which underlines the spatial nature of landscapes and the importance of people in landscapes. The second-level categories "*natural*", "*cultural/social*" and "*perceptual and aesthetic*" highlight the influence of the European Landscape Convention's definition of landscape by including natural, societal and perceptual aspects. The finest level of granularity of dimensions consists of detailed categories such as geology, land ownership and associations (cf. Table 2.2). Even though specific contexts might require adjusting this list, it presents a well-established tool with which landscapes can be characterised. In addition, the framework emphasises the complexity of landscapes and the potential interplay between natural and/or human factors which contribute to a landscape's character.

LCA L2 dimensions	**LCA L3 dimensions and references to Figure 2.1**
Natural	geology (2, 4), landform (2, 5, 10, 11), hydrology (1, 10, 12), air & climate (3), soils (2, 4), land cover / flora & fauna (1, 2, 5, 7 - 11, 13)
Cultural/social	land use (5, 7 - 9), settlement (6, 8, 9), enclosure (9), land ownership (8, 9), time depth (6)
Perceptual & aesthetic	memories (6, 8), associations (6, 8, 11), preferences (5, 10, 11, 13), sight (1 - 13), sounds (1 - 3, 5 - 13), smells (3, 5, 6, 8 - 11, 13), touch/feel (1 - 3, 5, 7 - 11, 13)

Table 2.2: Table of level two and respective level three Landscape Character Assessment dimensions. The numbers in brackets refer to the visual example(s) in Figure 2.1 where respective dimensions may be found

The resulting landscape character assessment not only gives an overview of the status quo of a landscape but can also be used by policy and decision makers to inform decisions about change (Scott, 2003; Tudor, 2014) (cf. Example 2.1). Important is the recognition of "subjective" and "objective" dimensions and the collection of respective data. Many of the dimensions contained in the second-level category *"natural"* and some of the dimensions contained in the category *"cultural/social"* can be elicited with sensors or with expert and increasingly non-expert knowledge. However, for gauging the perceptual dimensions the participation of laypeople is crucial. This poses a considerable limitation since public participation in landscape perception and preference research is biassed towards specific demographic groups (Bubalo et al., 2019) and thus calls for new methodologies of motivating and involving non-experts. However, before delving into questions of data generation and user motivation, I first cover an essential point: how do we perceive landscapes?

> Landscape character assessment (LCA) is a widely used framework to describe and compare landscapes through various dimensions, moving away from the notion of better or worse landscapes, towards landscapes being different.

2.3 Perceiving landscapes

Modern definitions of landscape foreground human perception as an integral part of landscapes, but what is perception? Perceiving can be summarised as interpreting the world around us and is crucial for sentient beings to interact with their surroundings (Helmholtz, 1825; Gibson, 1986; Hacker, 1995; Heft, 2010; Démuth, 2013; Raymond et al., 2017). Indirect perception theories generally assume the environment and objects therein impress themselves onto our sensory systems resulting, through inferences, in a response in our brain (Helmholtz, 1825; Hacker, 1995). Theories of direct perception on the other hand, revolve around the premise that information about an environment is directly - without additional cognitive processing - available in arrays and that perception is always relative to the perceiving subject, thus rejecting the subject-environment dichotomy whilst highlighting subject specific interactions with an environment (Gibson, 1986). The mentioned theories share common assumptions important for landscape perception and preference research:

- Experiencing or perceiving a given landscape encompasses not only the directly visible at a given moment, but the sum of available information. Thus, datasets used in landscape perception research should be generated in-situ and include different perceptual dimensions such as visual, auditory, olfactory, taste and haptic (e.g. being in-situ in a landscape compared to looking at an image of the same landscape results in a different perception of said landscape).
- What is perceived is relative to the perceiving organism. This implies a given environment is perceived differently depending on the perceiving subject's attributes, such as culture, demographics, past experiences, physical attributes and education (e.g. the northern tip of New Zealand can be perceived differently by a Māori child and a Swiss tourist. The former may perceive the landscape as the point from where spirits leave (Roberts, 2012), the latter a picturesque place where two oceans meet).

> Perceiving is the interpretation of one's surroundings through available sensory systems. How, what and why something is perceived can vary between individuals depending on the socio-cultural and demographic background of an individual as well as past experiences and physical attributes.

2.4 Affordances

Theories of direct perception postulate we perceive an environment's affordances which encompass the "perceptible properties of the environment that have functional significance for an individual" (Heft, 2010, p.18), in other words "what [the environment] offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1986, p.127). Affordances are thus the perceived possibilities of action inherent to an environment or object (Raymond et al., 2017; Heras-Escribano and Pinedo-García, 2018). For example, a kerb can be perceived as affording sitting to a child, whereas an adult perceives a border, separating the sidewalk from the street (cf. Heft, 2010).

Affordances are properties of the entities themselves (Gibson, 1986; Heft, 2010; Raymond et al., 2017), however, only through perceiving do affordances become relevant, highlighting the subject specific and interactional properties of affordances. A perceiving subject "may or may not perceive or attend to [an] affordance, according to [its] needs, but the affordance, being invariant, is always there to be perceived" (Gibson, 1986, p. 139). Therefore, landscapes and the objects therein have a vast number of affordances entailing all imaginable possibilities of action, independent of the perceiving organism (cf. Gibson, 1986; Rietveld and Kiverstein, 2014). A perceiving organism merely perceives a small subset of available affordances and acts upon an even smaller number. Perceived affordances are acted upon depending on the perceiving individual's momentary capabilities and needs as well as socio-demographic and cultural background (Gibson, 1986; Gaver, 1991; Heft, 2010; Ramstead et al., 2016; Heras-Escribano and Pinedo-García, 2018).

The concept of affordances has been widely adopted in design studies such as human computer interaction (HCI) and interaction design (cf. Gaver, 1991; Hartson, 2003) (albeit definitions and applicability are debated (Kaptelinin and Nardi, 2012)) as well as in landscape perception research (cf. Heft, 2010; Gillings, 2012; Raymond et al., 2017; Raymond et al., 2018). Seeing the interactional character of affordances, they are particularly interesting in discussions of a landscape's *"cultural/social"* and *"perceptual & aesthetic"* dimensions as well as a landscape's cultural ecosystem services (cf. Raymond et al., 2018). Even though the complementarity of affordance theory to landscape research is debated (cf. Heft, 2010), analysing affordances can arguably add to existing landscape perception literature. In particular, by providing a novel approach for including otherwise uncaptured dimensions such as identifying fast changes in place identity (Raymond et al., 2017), investigating recreational landscapes (Hansen, 2021), using niche construction theory to overcome the nature - culture dichotomy (Heras-Escribano and Pinedo-García, 2018) and exploring cultural affordances (Ramstead et al., 2016).

> Affordances are the possibilities of action inherent to an object or environment. Individuals perceive different affordances and choose whether or not they wish to take action.

2.5 Sense *in* place: sensory dimensions of landscapes

As we have established in the definition (cf. Chapter 2.1.2), landscapes are perceived areas with a distinct character which influence and are influenced by our actions. Interacting consists not only of visual appreciation of a given environment, but is a multi-sensory process (cf. Lynch, 1960; Tuan, 1975; Sepe, 2013). The exploration of how different senses influence our perception of landscapes has motivated inquiries into visual (Tveit et al., 2006), auditory (Aiello et al., 2016; Chesnokova and Purves, 2018), olfactory (Quercia et al., 2015) and haptic (Brown, 2017) dimensions of landscapes.

2.5.1 Visual perception

Landscapes have a visual character which is defined as "the visual expression of the spatial elements, structure and pattern in the landscape" (Ode et al., 2008, p. 90). The visual dimension of landscapes has thus far often implicitly received most attention in landscape perception and preference research. From urban planning to protecting natural landscapes, the visual dimension of landscapes is privileged. Visual qualities of landscapes are commonly assessed or monitored using a framework, most prominent of which are the Scenic Beauty Estimation (SBE) and the Visual Resource Management (VRM). These frameworks are either reliant on field data or annotated images (cf. Tveit et al., 2006). Consequently, images and to some extent videos have been used in landscape perception and preference research, most commonly in studying landscape preferences.

Studies frequently involve participants being shown varying landscape photographs and being asked to rate the photographs according to their subjective preference on a predefined scale (Kaplan and Herbert, 1987; Kaplan and Kaplan, 1989), submit subjective judgements on bipolar landscape assessment criteria (cf. Matijošaitienė et al., 2014), group images which are perceived to belong to some common category (Petrova et al., 2015) or describe videos in interviews (Williams et al., 2012). The findings from visual landscape character research have led to the identification of visual character indicators (e.g. historicity & ephemera) and gradients (e.g.

stewardship to naturalness & disturbance to coherence), which are used to describe various aspects of a landscape's visual character (for a detailed discussion see (Ode et al., 2008; Tveit et al., 2006)). Mentioned indicators are argued to allow the inclusion of a greater variety of underlying data (Ode et al., 2008; Tveit et al., 2006) whilst reducing complexity by focusing on a single visual variable.

> The visual arrangement of landscapes – categorised through indicators and gradients - and the visual perception thereof are distinct dimensions of a landscape's character.

2.5.2 Auditory perception

Acoustic characteristics are another important perceptual dimension of landscapes. Schafer (1993) coined the term soundscape as the acoustic environment. Soundscapes are composed of various local acoustic milieus which are auditory microclimates of objects (Roulier, 1999; Farina, 2014) and contribute to a landscape's distinct character. Landscapes can include a multitude of sound emitters, ranging from natural sounds to anthropogenic noise[1]. Sound emitters can be categorised as one of three sound sources: geophony, biophony and anthropophony (Krause, 2008; Farina, 2014; Pavan, 2017):

Geophony: natural sounds of inanimate sound emitters (rain, wind, rivers, waves etc.)

Biophony: natural sounds of animate sound emitters (fauna and flora)

Anthropophony: unnatural sounds of anthropogenic sound emitters (car, train, concert etc.)

Combinations of these sound sources contribute to the distinct character of a landscape. For example, the combination of sounds are very different when standing on the ocean shore as opposed to walking through the rainforest. The literature shows the importance of sounds in landscapes and how these influence our perception and behaviour (Sepe, 2013; Farina, 2014), especially since the sounds we are exposed to can impact our health and well-being (Andringa and Lanser, 2013; Aiello et al., 2016).

[1] Note how in English the terminology of acoustic emissions tells us something about how these are perceived: sound has a neutral connotation whereas noise is rather negative

Acoustic emissions – geophonies, biophonies and anthropophonies – combine to soundscapes contributing to the distinct character of a landscape and influencing our perceptions and preferences.

2.5.3 Olfactory perception

As (Lefebvre, 1992, p. 197) states: "[t]angible space possesses (although these words are not ideal here) a basis or foundation, a ground or background, in the olfactory realm. If sensual rapture and its antithesis exist anywhere, if there is any sphere where, as a philosopher might say, an intimacy occurs between 'subject' and 'object', it must surely be the world of smells and the places where they reside". The olfactory dimension thus plays a crucial role in our perception and preference of landscapes, especially since smells can directly invoke emotional and physiological responses and trigger various memories (Hoover, 2009). However, whilst the auditory and especially the visual dimensions of landscapes are privileged in research, smells and odours are often neglected (Porteous, 1985; Henshaw, 2013).

Odours have been found to be closely linked to long-term memory and are remembered longer than visual cues (Engen, 1991), highlighting their importance for landscape associations. Humans can perceive a vast variety of different odours (Bushdid et al., 2014) and associate many of these with specific environments or an imagined socio-economic identity of a respective landscape (Quercia et al., 2015). The various odours contributing to the distinct character of a landscape constitute an environment's smellscape, which is defined as "the totality of the olfactory landscape, accommodating both episodic (fore-grounded or time limited) and involuntary (background) odours" (Henshaw, 2013, p. 5).

Research on the olfactory dimension of landscapes has primarily focused on negative aspects of odours and their influence on human health and well-being calling for the exploration of positive aspects of olfactory dimensions of landscapes (Quercia et al., 2015). Recent research has found the perception of pleasant odours to vary more between individuals than cultures (Arshamian et al., 2022) suggesting the notion of pleasant olfactory experiences in landscapes to be shared across cultures. Smellscapes not only influence individual perceptions of a respective landscape, but have been found to also segregate race, class, gender and ethnicity (Pennycook and Otsuji, 2015). For example, historically the wealthier population would commonly live upwind of industrial areas, whereas the poor population would be made responsible *for* and made to live *in* malodorous areas (Howes and Classen, 2013). Recently, research into the relations between language and smells has suggested that language could influence our perception of odours and thus lead to individual subject dependent smellscapes (Pennycook and Otsuji, 2015).

> A landscape's smellscape accommodates episodic and involuntary odours which are important contributions to a landscape's distinct character, albeit perceived differently depending on the socio-demographic background of the perceiving individual.

2.5.4 Haptic perception

An often neglected perceptual dimension in landscape perception and preference research is the haptic dimension (Tuan, 1989; Brown, 2017). Experiencing the various surface textures of a landscape through touching or feeling is an integral part of landscape perception (Sepe, 2013; Brown, 2017) and has been linked to human well-being (Lea, 2008; Obrador-Pons, 2007; Straughan, 2012). In contrast to the other perceptual dimensions mentioned, a haptic experience requires direct contact (Sepe, 2013) and cannot be sensed from a distance. It has been argued that "the greater part of landscape experience belongs to the sensorium of the tactile, the poetries of material and touch" (Corner, 1992, p. 250). Not only can surface textures motivate physical activity (Brown, 2017), they also afford different modes of mobility – e.g. cycling (Spinney, 2006), running (Lorimer, 2012) and walking (Lund, 2005) – influencing our perception of and therefore behaviour in a given landscape (Ingold, 2005). Haptic experience of a landscape is not limited to the perception of surface texture, but also includes humidity and temperature as well as other weather related phenomena (Corner, 1992; Szczepańska et al., 2013).

> Surface textures can be touched and felt and are closely linked to other perceptual dimensions contributing to a landscape's distinct character, albeit mostly disregarded in landscape perception and preference research.

2.6 Sense *of* place and sense *through* place: attachment, interaction and appreciation

The sense of place literature goes beyond describing landscape perception through sensory experiences and sheds light on more subjective dimensions of experiencing our surroundings. Sense of place concepts "weave[s] together the varied concerns of perception, cognition, individual behavior, cultural value, symbolism, and meaning"

(Foote and Azaryahu, 2009, p. 99) and are crucial for exploring landscape perception. The contemporary sense of place literature is particularly interested in the socially constructed attachment to places and what meanings we ascribe to specific places (Tuan, 1975; Relph, 1976; Foote and Azaryahu, 2009; Raymond et al., 2017; Peng et al., 2020). Understanding these dimensions is crucial since places are "significant centres of our immediate experiences of the world" (Relph, 1976, p. 141), however "the casual eradication of distinctive places and the making of standardized landscapes [that] results from an insensitivity to the significance of place" (Relph, 1976, Preface). This underlines the importance of complementing the physical properties of an area by including immaterial and intangible dimensions as explored under the frameworks of cultural ecosystems services (Van Berkel and Verburg, 2014; Fish et al., 2016; Fagerholm et al., 2020). Intangible dimensions of landscapes have emerged as fundamental aspects when exploring how landscapes are perceived (Vecco, 2020) and allow us to transcend traditional approaches of comparing the physical properties of landscapes, towards understanding how humans as individuals embedded within a socio-cultural and demographic context perceive landscapes. Most important dimensions in contemporary frameworks of capturing and exploring the intangible dimensions of landscapes include identity, tranquility, recreation, heritage, spiritual and religious values as well as inspiration (Bieling, 2014; Van Berkel and Verburg, 2014; Fish et al., 2016; Wartmann and Purves, 2018; Fagerholm et al., 2020).

2.6.1 Identity

Two such intangible dimensions are a landscape's identity and how we identify with landscapes, two different perspectives which should be disentangled (for an overview see (Peng et al., 2020)). A landscape's identity encompasses a shared notion or a regional consciousness of the tangible and intangible dimensions of a landscape which is reproduced through the institutionalisation of a region - through, for example, the educational system, media, governance and economics - and the shared expectations towards a region (Paasi, 1986; Paasi, 2002). In other words, landscapes have identities which are known and perceived by individuals within the same socio-cultural context making one landscape distinguishable from another (e.g. down-town Bern compared to the Swiss Alps). Language is argued to be one of the most common features making an area distinctive (Peng et al., 2020) and is comprised of words describing the relationships between individuals and their surroundings (Paasi, 1986). It should be noted that landscape identity and landscape character are conceptually similar but come from different schools of thought: landscape character is a more holistic interpretation whereas landscape identity concerns itself with the distinctive properties of a given landscape and the way in which these are reproduced through cultural influence.

The identity an individual builds in relation with a particular landscape on the other hand revolves around a personal connection on the individual level towards a specific landscape (Bieling, 2014) and includes "those dimensions of self that define the individual's personal identity in relation to the physical environment by means of a complex pattern of conscious and unconscious ideas, feelings, values, goals, preferences, skills, and behavioural tendencies relevant to a specific environment" (Proshansky, 1978, p. 155). When exploring individuals' landscape identities, the subjective concepts of home and belonging become central (Bieling, 2014) underlining its highly subjective nature. Commonly, a landscape's shared identity is slow to evolve and manifests over time whereas an individual's landscape identity can be highly dynamic (Raymond et al., 2017). Mountains were perceived as threatening and dangerous whereas now, mountains are admired as awe inspiring feats of nature that afford many activities (Fleming, 2004), exemplifying a slow and gradual change in the shared perception of a specific landscape. On the other hand, the area, and in extension the landscape, where one is married or divorced can suddenly be perceived differently (Raymond et al., 2017) exemplifying a sudden and fast change in how a landscape is perceived. Therefore, including fast changing perceptions in landscape perception research can provide valuable insights in time-specific perceived dimensions which has been called for (Raymond et al., 2017).

> A landscape's identity is a shared idea of what makes a specific landscape unique and invokes shared expectations towards a region. How someone identifies with a landscape revolves around a personal connection between an individual and a specific landscape.

2.6.2 Tranquillity

Not only do people perceive the presence of sounds, but they also appreciate the absence of sounds or unique combinations thereof. Tranquillity is broadly defined as "calmness, serenity, and peace" (Herzog and Bosley, 1992) and is commonly attributed to specific landscapes (Russell and Pratt, 1980). The literature finds tranquillity to be an important and valued intangible dimension of landscapes (Wartmann and Purves, 2018; Fagerholm et al., 2020) offering a welcomed contrast to fast-paced everyday life (Wartmann et al., 2021b). Investigation into tranquil landscapes has found people to associate tranquillity with peaceful, serene, quite and relaxing environments with restorative properties (Kaplan and Kaplan, 1989; Korpela et al., 2001). The perceived importance of the restorative property and having access to tranquil areas is underlined by tranquillity being a prominent term used by people when asked about landscapes (Fagerholm et al., 2020).

Forests and water bodies in particular are highly correlated with a feeling of tranquillity and peace whereas anthropogenic features have been found to reduce perceived tranquillity (Ulrich, 1983; Kaplan and Kaplan, 1989; Wartmann et al., 2021b). However, the literature shows the importance of pockets of tranquillity in urban environments and that certain combinations of natural and anthropogenic features can positively influence perceived tranquillity (Hadavi et al., 2015). Nevertheless, the perception and appreciation of sound, and in extension tranquillity, remains highly subjective and depends on the perceiving individual (Coates, 2005; Jackson et al., 2008). It is thus unsurprising that the way individuals talk about tranquillity and how this concept is captured in different corpora can vary greatly (Jackson et al., 2008; Chesnokova et al., 2019).

> Tranquility describes a landscape's ability to induce a feeling of peace, relaxation, serenity or calmness as a contrast to fast-paced everyday life.

2.6.3 Recreation

Recreation - defined here as "leisure time activities and feelings of satisfaction, enjoyment and happiness" (Hansen, 2021, p. 129) - is an important aspect of human life and has been linked to increased well-being (cf. Abraham et al., 2010; Hansen, 2021) with outdoor activities potentially resulting in greater benefits than indoor activities (Thompson Coon et al., 2011). Landscapes afford a wide array of intangible dimensions linked to recreation such as social interactions and happiness as well as active recreational affordances such as hiking, gardening and fishing (Fagerholm et al., 2020). The perceived recreational affordances can vary greatly depending on the demographic and socio-cultural background of an individual in combination with the individuals abilities and needs (Hadavi et al., 2015). In addition, having areas with recreational affordances in the vicinity of home is shown to positively influence mental, physical and social well-being (Lopes et al., 2018). However, access to these areas is dependent on available forms of mobility and perceived safety, especially regarding children (Fagerholm and Broberg, 2011; Oliver et al., 2016). Understanding the perceived recreational affordances of everyday lived landscapes can thus shed light on the use of near infrastructure, complementing contemporary research on areas deliberately visited for recreation such as golf courses or football fields.

> Landscapes offer various recreational affordances which are leisurely activities that a landscape invites performing, resulting in feelings of enjoyment, satisfaction and happiness.

2.6.4 Heritage

Exploring a landscape's dimensions not only sheds light on how a landscape is currently perceived and used, but can also point towards a landscape's history. Heritage values are defined as "special or historic features within a landscape that remind us of our collective and individual roots [...] in our natural and cultural environment" (Tengberg et al., 2012, p. 16). These features can include knowledge and stories about a specific area that conjure certain imaginations about a landscape (Bieling, 2014) such as the legends of Loch Ness (Boz, 2020), as well as anthropogenic structures such as buildings with historical significance (Capelo et al., 2012; Bieling, 2014). Heritage values are thus considered as cultural memories deeply embedded in landscapes (Tengberg et al., 2012) and link past societal and cultural achievements and interactions with present landscapes (Capelo et al., 2012).

What types of heritage values are perceived and how these are perceived depends on the individual's socio-cultural background (Capelo et al., 2012). However, heritage values are commonly shared within a larger group whilst simultaneously defining said group (Lowenthal, 1998). In other words, perceiving similar heritage values can indicate belonging to a similar socio-cultural background. Identifying and understanding heritage values of everyday lived landscapes can thus tell us something about subjective and individual perceptions of landscapes as well as culturally shared notions of historical remnants in landscapes.

> A landscape's heritage values encompass historic anthropogenic features and culturally significant and shared notions of a landscape that remind us of our individual or collective past.

2.6.5 Inspiration

Landscapes spur creativity and inspiration which is reflected in creative, philosophical and artistic representations of landscapes in paintings, photographs and writing (Heft, 2010; Bieling, 2014; Fish et al., 2016; Berr and Schenk, 2019). The dimension of inspiration is commonly related to the notion of discovery, stimulating thought, spiritual experiences as well as recreational activities and tourism (Fredrickson and Anderson, 1999; Tengberg et al., 2012; Bieling, 2014; Van Berkel and Verburg, 2014; Fish et al., 2016). This highly interrelated nature of the dimension inspiration hints at the general interconnectedness of intangible dimensions of landscapes. The inspirational character of landscapes can be found as artifacts in arts and folklore (Bieling, 2014) reflecting induced creativity.

> A landscape's inspirational properties manifest in increased creativity and can provoke thought, invite discovery and are commonly connected to spiritual or recreational dimensions.

2.6.6 Ethical, spiritual and religious values

Ethical, spiritual and religious values belong to the least commonly mentioned intangible dimensions of landscapes within the reviewed literature (Bieling, 2014; Fagerholm et al., 2020). Religious, spiritual and ethical values are highly connected with the concepts of heritage, identity and inspiration (cf. Bieling, 2014; Aulet and Vidal, 2018) and are commonly, if existent and important in a given cultural context, deeply rooted within the respective culture. Landscapes can contain infrastructure important for acting out religious or spiritual activities which contribute to the heritage value and identity of a landscape (Aulet and Vidal, 2018). Landscapes can also encompass historically significant places without apparent anthropogenic influence such as Te Reinga Wairua, known today as Cape Reinga, where spirits leave New Zealand in Māori culture (Roberts, 2012) or the sacred land of the gods, areas of varying size (e.g. sanctuaries to meadows) marked by boundary stones (Horster, 2010).

Areas with ethical, spiritual or religious values can be found where important spiritual or religious events once occurred or which are otherwise important in a belief system (Dewsbury and Cloke, 2009; Horster, 2010; Roberts, 2012; Zhang and He, 2021). These areas and how they are perceived can be specific for small groups such as on the family level (Filtchenko, 2011) up to large internationally recognised areas (Zhang and He, 2021). The location and significance of these landscapes are commonly known to persons within said spiritual or religious context and knowledge is passed down through written and spoken language. Designating areas as spiritual, sacred or religious changes the way in which these landscapes are used, introducing a set of new affordances and excluding others (Sachdeva, 2017). Spiritual and religious values are thus important in understanding culturally specific perceptions of landscapes and identifying the variations in perceived affordances in landscapes.

> A landscape's religious values are perceived by groups of individuals of varying sizes and afford religious or spiritual activities whilst commonly contributing to the heritage value and identity of a landscape.

2.7 Landscape perception data generation

Using a highly diverse underlying dataset of landscape perceptions has been identified as crucial for successful landscape research and planning efforts (Bruns et al., 2015; Bubalo et al., 2019). According to the *European Landscape Convention*, active public participation is an integral part of the research domain and must be encouraged (for a summary see (Jones, 2007)).

Traditional methods of generating landscape perception data revolved around expert opinions (Dakin, 2003; Jones, 2007; Swanwick, 2009; Krueger et al., 2012) or surveys (Bromley, 1981; Hastak et al., 2001; Ruff and Maddison, 1994). Although these methods have proven to generate high quality data for scientific research, they are often accompanied by major limitations including financial or time restrictions. Crowdsourcing on the other hand has been identified as cost efficient, allows for quick data collection and includes users with diverse backgrounds (Eickhoff, 2018).

In recent years crowdsourcing and citizen science have become increasingly popular allowing non-expert users to generate data used in a research context (cf. See et al., 2016). Two general categories of crowdsourcing have been identified: passive crowdsourcing and active crowdsourcing (See et al., 2016). Passively crowdsourced data is generated for a different purpose than specific research questions and commonly consists of social media data from popular platforms such as Twitter, Instagram and Flickr (Aiello et al., 2016; See et al., 2016; Gao et al., 2017; Figueroa-Alfaro and Tang, 2017; Bubalo et al., 2019). Major advantages of using such datasets include low acquisition costs, the general availability and the ease of access, the large coverage in space and time and the amount of available data (Bubalo et al., 2019).

Actively crowdsourced data on the other hand – data actively contributed by users as part of a targeted effort to collect specific data (See et al., 2016) – has the advantage of being particularly relevant for a given research question. Questions of how to motivate new users to join and existing users to continuously generate data thus become important (Fritz et al., 2017). Commonly, active crowdsourcing efforts incorporate rewards to motivate users to participate (See et al., 2013; Bayas et al., 2016; Morschheuser et al., 2016), which can become a financial restriction. In addition, it has been found that active crowdsourcing projects can be accompanied by imbalances in the gender, age and educational backgrounds of participants (cf. Brossard et al., 2005; Bubalo et al., 2019). This is problematic since younger individuals are generally not included in underlying landscape perception datasets (Bubalo et al., 2019).

Thus, it is of utmost importance that new approaches to active crowdsourcing, especially new forms of motivating users to continuously contribute high quality data, are explored. Recent research suggests gamification or gamified crowdsourcing efforts as a viable and powerful new approach (Hamari et al., 2014; Morschheuser et al., 2016; Bubalo et al., 2019).

> Traditional methods of landscape data generation revolved around expert opinions, surveys and questionnaires. These are complemented by contemporary approaches utilising crowdsourcing and gamification.

2.8 Gamification

Gamification is defined as "hedonic or entertainment-oriented technologies being re-appropriated for productive use" (Koivisto and Hamari, 2019, p. 191), in other words: incorporating entertaining or playful elements into an existing process (Hamari et al., 2014; Morschheuser et al., 2016) and as such is a motivational tool. Commonly included game-elements include points, achievements or badges, levels and a story or narrative (cf. Farzan et al., 2008; Guin et al., 2012; Cheong et al., 2013; Denny, 2013; Morschheuser et al., 2016). Applications commonly include ludic and serious elements to varying degrees. Ludic is associated with playing and refers to invoking undirected and spontaneous play such as commonly found in entertaining video games, whereas serious is associated with working and capitalises on targeted and goal-oriented incentives such as in educational software (Dubbels, 2013). Gamification thus spans a gradient from ludic to serious and has been found to positively influence intrinsic and extrinsic motivation resulting in increased participation and higher data quality in crowdsourcing applications (Hamari et al., 2014; Morschheuser et al., 2016).

Research on gamified crowdsourcing efforts has included curating and generating geographic information (Celino et al., 2012; Celino, 2015; Bayas et al., 2016), capturing people's spatial ability (Coutrot et al., 2018a; Coutrot et al., 2018b), curating or translating text corpora (Roa-valverde, 2014; Silva, 2016) or assessing document relevancy by relating terms and concepts (Eickhoff et al., 2012). This shows the range and widespread applicability of gamification in research contexts. In landscape perception research gamification remains uncommon and has mainly focused on land cover data generation to investigate questions of land cover perception and land cover product accuracy (Bayas et al., 2016). The literature suggests that gamified crowdsourcing efforts can lead to large amounts of data with sufficiently high quality to address certain research topics (Bayas et al., 2016; Bubalo et al., 2019). This is especially important since gamification has further been identified as a way to increase user retention and include younger audiences than typically involved in landscape data generation (Bubalo et al., 2019).

From the perspective of aforementioned sensory (*sight*, *sound*, *smell/taste* and *touch/feel*) as well as intangible (*identity*, *tranquillity*, *recreation*, *heritage*, *inspiration* and *ethical, spiritual and religious values*) dimensions, individuals have the possibility of perceiving and experiencing most dimensions of a given environment when they are in-situ. Naturally, location-based games come to mind as the data generated is inherently in-situ. In a location-based game, certain in-game interactions only become available at specific real world locations (Leorke, 2018). Moving around and changing one's real world location is thus an integral part of the game-play without which the game cannot be fully experienced (Leorke, 2018). Since a user must go to specific real world locations to enable virtual in-game features, this in-situ nature of the user can be exploited to generate high quality in-situ data (Celino, 2015). Using location-based games to generate data for (geospatial) research purposes has gained traction (cf. Matyas, 2007; Davidovic et al., 2013; Yanenko and Schlieder, 2014; Celino, 2015; Bayas et al., 2016; Morschheuser et al., 2016). Nevertheless, research on location-based games to motivate a diverse audience to generate landscape perception data in the form of natural language descriptions seems lacking. This calls for inquiries into how such a location-based game can be developed and implemented to attract and retain a large number of diverse users.

> Gamification revolves around adding playful elements to a process and has been found to increase user motivation and retention as well as reduce user bias. Gamification has been called for in landscape perception research as a possible approach to generate a more heterogeneous dataset.

2.8.1 Mechanics, dynamics and aesthetics (MDA) Framework

A common framework for implementing gamified applications is the mechanics, dynamics and aesthetics (MDA) framework (Hunicke et al., 2004). The MDA framework has seen widespread adoption in designing (cf. Ivanjko, 2019) and analysing (cf. Kusuma et al., 2018) gamified applications as well as entertainment oriented games. At its core, the framework reduces applications to their aesthetics, dynamics and mechanics and includes both the perspectives of designers of an application as well as the consumers thereof. The mechanics component of an application encompasses the underlying application logic in the form of necessary algorithms and data representations (Hunicke et al., 2004). Aspects of an application that are influenced by a player's interactions or that influence how a player behaves in the application are summarised as an application's dynamics (Hunicke et al., 2004). Finally, an application's aesthetics captures a user's emotional response towards specific parts of an application (Hunicke et al., 2004). According to the MDA framework, users consume and designers create applications and therefore have fundamentally different perspectives. Users experience an application's aesthetics which manifest through the application's dynamics which in turn are built on the application's mechanics. Designers on the other hand elicit application requirements which are translated into underlying system mechanics, which afford interactions through dynamics, which in turn result in an application's aesthetics. As such, the MDA framework has been used in a number of gamified participatory projects such as in disaster risk management (Frisiello et al., 2017), collecting image descriptions (Ivanjko, 2019) and gamified education (Kusuma et al., 2018).

> The mechanics, dynamics and aesthetics (MDA) framework revolves around users' emotional reaction to applications as well as interactions and underlying logic and takes the users' as well as designers' perspectives into account.

2.9 Natural language processing for landscape research

We communicate using a wide variety of different languages (Joshi, 1991). In regards to landscapes, languages convey emotions and meanings through words and phrases that characterise the relationship between an environment and the individuals therein, including their emotional ties with a particular landscape (Paasi, 1986, p. 131). Natural language - a language "that has not been specially constructed, whether for general or specific purposes, and is acquired by its users without special instruction as a normal part of the process of maturation and socialization" (Lyons and Le Page, 1981; Lyons, 1991, p.216) - can thus offer insights into the inner workings of how people experience and perceive their environments and is, in extension, an ideal starting point to exploring landscape perceptions. Therefore, having a corpus of natural language landscape descriptions and respective metadata allows landscapes to be compared by their distinct characters, how they are perceived and how these vary within and between individuals (Tudor, 2014; Derungs and Purves, 2016; Fagerholm et al., 2020).

Various computational linguistic approaches are found under the umbrella term of *Natural Language Processing (NLP)* which revolves around computationally extracting and modelling natural language (Coughlin, 1990; Joshi, 1991; Pustejovsky and

Stubbs, 2013). Natural language processing encompasses a wide range of methods and algorithms, from Part-of-Speech (PoS) tagging, over dependency parsing, to complex machine learning algorithms such as using vector representations of a respective language to compare and characterise specific traits (Hirschberg and Manning, 2015). These varying approaches of extracting relevant data from natural language sources has resulted in a plethora of inquiries into landscapes through language.

Natural language processing is a viable approach of identifying salient landscape features (Derungs and Purves, 2014; Huai and Van de Voorde, 2022), investigating intangible dimensions of landscapes such as tranquillity, recreational use or cultural ecosystem services more generally (Chesnokova and Purves, 2018; Wartmann and Purves, 2018) and analysing sentiments towards landscapes (Huang et al., 2013; Klettner et al., 2013). Further studies have extracted fictive motion from texts (Egorova et al., 2018a; Egorova et al., 2018b), compared different sources of natural language through spatial folksonomies (Derungs and Purves, 2016), identified basic levels in landscape terminology and compared these to other widely known concepts such as body parts in different languages (Putten et al., 2020), extracted landscape character measures (Koblet and Purves, 2020) and compared landscapes through vectorisation and clustering of terms (Huai and Van de Voorde, 2022). This list is in no way extensive, however it goes to show the wide variety of research topics at the intersection of landscape research and linguistics.

Analysing natural language can lead to insights into how individuals or groups of individuals perceive landscapes, however, natural language processing is accompanied by various limitations. The interrelatedness and context specificity of terms in a given language makes algorithmic extraction of underlying meanings complex. For example, words can have multiple meanings and syntactic relations (Joshi, 1991; Filtchenko, 2011) which are not trivial to identify. However, for a number of specific tasks, such as part of speech tagging, error rates of natural language processing approaches are low enough for computational analyses, especially using well trained models (Joshi, 1991; Manning, 2011). Nevertheless, landscape specific training data for natural language processing remains sparse. In particular, rich corpora capturing differences in how different cultures or demographics perceive landscapes are needed. This calls for landscape specific training datasets to improve the quality of existing algorithms or more qualitative approaches to analysing natural language in regards to landscapes.

> Natural language processing revolves around computer aided analyses and processing of unstructured text and is an integral part of generating and analysing large datasets in landscape perception research focusing on the extraction of knowledge from natural language.

2.9.1 Annotating crowdsourced natural language

Natural language processing is a powerful approach of gaining valuable insights into large textual datasets. However, unsupervised or naive computational approaches relying solely on statistical inferences to extract meaning from language (e.g. using term frequencies and clustering methods (cf. Kilgarriff, 2001; Gries, 2009)) quickly reach their limits due to the complexity of natural language. Natural language processing algorithms are not well equipped for example to identify contradictions in natural language (Bowman et al., 2015), to identify relevant sentiments, especially when multiple sentiments or the combination of factual and sentiment statements are present (Wiebe et al., 2005), to relate images with natural language describing the visual content (Reed et al., 2016) or to detect irony and sarcasm (Davidov et al., 2010). For these and similar tasks, annotation in some form becomes vital.

Annotating natural language corpora to complement computational approaches is a commonplace practice to extract landscape characteristics or dimensions (cf. Tyrväinen et al., 2007; Plieninger et al., 2013; Wartmann et al., 2018; Chesnokova and Purves, 2018; Koblet and Purves, 2020; Baumeister et al., 2022). This is particularly valuable when using natural language as a proxy for perception to compare different landscapes and experiences therein. Annotation broadly describes the process of supplementing (textual) data with "metadata that provides additional information [about the text]" (Pustejovsky and Stubbs, 2013, p. 1). The provided meta-data is commonly machine readable and complements existing statistical methods of knowledge extraction by providing an additional layer of information, sharing many similarities with various forms of qualitative content analysis (cf. Hsieh and Shannon, 2005).

Annotating texts commonly involves an iterative process in which guidelines are prepared with which annotators work through a corpus and label the data with respective meta-data (cf. Crang and Cook, 1995; Pustejovsky and Stubbs, 2013; Wartmann et al., 2018). A specific methodological approach of annotating texts are the techniques of qualitative coding which is broadly defined as "the process of defining what the data are about" (Charmaz, 2006, p. 43). In qualitative coding, data such as interview transcripts or natural language are reduced to codes which are combined to categories and themes (cf. Charmaz, 2006; Stålhammar and Pedersen, 2017). These iterative approaches can lead to new insights, especially when starting with the premise that relevant codes and categories emerge from the data, as is common within constructivist approaches of grounded theory (cf. Charmaz, 2006; Stålhammar and Pedersen, 2017).

> Annotating or qualitative coding is the iterative process of adding additional meta-data to an existing dataset, making unstructured data machine interpretable.

2.9.2 Vectorisation of natural language

Converting words, sentences and documents to vectors is a key part of natural language processing (cf. Mikolov et al., 2013a; Mikolov et al., 2013b; Pennington et al., 2014; Devlin et al., 2019; Liu et al., 2019) and has had significant influences on accuracy and quality of downstream natural language tasks such as translation, sentiment analysis and topic modelling. Approaches such as Word2Vec (Mikolov et al., 2013a; Mikolov et al., 2013b), Doc2Vec (Le and Mikolov, 2014) and GloVe (Pennington et al., 2014) have received considerable attention in natural language processing and have been used in a range of scientific inquiries. Examples are diverse and range from improving text classification tasks (Lilleberg et al., 2015; Trieu et al., 2017), over detecting urban land use distributions (Yao et al., 2017) and exploring biomedical concepts (Muneeb et al., 2015), to various approaches of sentiment analyses (Bilgin and Şentürk, 2017; Onan, 2021). Recent advances have focused on Bidirectional Encoder Representations from Transformers (BERT) to translate natural language to multidimensional vectors, which has led to further increases in accuracy of downstream tasks (cf. Devlin et al., 2019; Liu et al., 2019) whilst reducing training time (cf. Vaswani et al., 2017; Liu et al., 2019). Scientific inquiry has focused on improving transformer based approaches, for example with a Robustly Optimised BERT Pretraining Approach (RoBERTa) (Liu et al., 2019) or generalized autoregressive pretraining for language understanding (XLNet) (Yang et al., 2019). A common goal of many approaches facilitating the translation from natural language to a multidimensional vector space is to capture relevant semantics within the generated vectors (Lilleberg et al., 2015; Muneeb et al., 2015; Mickus et al., 2020; Yenicelik et al., 2020; Penha and Hauff, 2020). A widely used textbook example shows that vector representations not only capture semantics (a queen is commonly a women, a king commonly a man), but also allow for vector based calculations (e.g. king - man + woman = queen (Ethayarajh et al., 2020)). In addition, vector representations of natural language open the door for similarity calculations such as cosine similarity scores, which is a common practice when comparing documents through vectors (Boyack et al., 2011; Li and Han, 2013; Wartmann and Purves, 2018; Takano et al., 2020).

> Translating natural language (individual terms up to whole documents) to a multidimensional vector space captures semantics within numeric values allowing for vector based calculations to be performed on natural language.

2.10 Research gaps

How we perceive landscapes and places forms "a continuum that has direct experience at one extreme and abstract thought at the other" (Relph, 1976, p. 9). This thesis aims to contribute to bridging the gap between these extremes by capturing and exploring various dimensions from direct experiences of landscapes to abstract thoughts by analysing actively crowdsourced natural language landscape descriptions.

Many publications have shown the rich insights that natural language processing of passively crowdsourced data (e.g. social media data) allows. However, actively crowdsourcing everyday lived landscape perception data is underrepresented or missing altogether. Research has found active crowdsourcing to be a time and cost efficient tool of generating high quality data, however, questions of how to best motivate users to continuously participate remain unanswered. Gamification has been proposed as a potential approach of user engagement, however, gamified systems of landscape relevant data generation are scarce at most.

The literature agrees that capturing multiple sensory dimensions of landscapes is a crucial step towards a more holistic understanding of human-landscape interactions. However, collecting and exploring the visual qualities of landscapes remains predominant with the exploration of other sensory experiences lagging behind. Intangible dimensions of landscapes have also received considerable attention, however, research mainly focuses on recreation, tourism and tranquility. Linking perceived intangible dimensions of landscapes with sensory experiences seems altogether missing, calling for shifting focus from solely investigating landscapes in terms of their visual character to the inclusion of other sensory experiences such as the haptic, olfactory and auditory dimensions. Further, many approaches have captured particularly pleasing or idealised landscapes. However, we spend most of our time in mostly urban or residential environments. This calls for research into how we perceive these everyday lived landscapes, what we appreciate or dislike about these environments and what features are salient in our daily lives.

Finally, inquiries into landscapes commonly generate small high quality datasets, many of which are moderated and annotated with additional information. However, large spatially located landscape relevant text collections are lacking. Therefore, there is a need to explore novel methods of generating large corpora. Document vectorisation and similarity score calculations have seen common adoption to identify similar documents. However, using mentioned approach to generate a large landscape specific corpus with the help of a small curated corpus is missing.

2.10.1 Research questions

In light of the presented literature, the identified research gaps and the overarching research question set out in the introduction, this thesis strives to investigate following research questions:

- **RQ1:** How can we collect natural language landscape descriptions about everyday lived landscapes that capture the rich diversity found within and between cultures and socio-demographic groups through a gamified application?

- **RQ2:** How can we analyse a rich corpus of actively crowdsourced natural language landscape descriptions of participants' everyday lived landscapes using both quantitative and qualitative methods and what added benefit does such a dataset provide?

- **RQ3:** How can a carefully curated and annotated corpus of natural language landscape descriptions be used to identify similar landscape specific documents in other text collections?

3 Towards Gamification: StarBorn and Percy's World

> *Beyond the horizon of the place we lived when we were young. In a world of magnets and miracles. Our thoughts strayed constantly and without boundary.*
>
> — **Pink Floyd**
>
> (Band)

Public participation in data collection efforts has many advantages compared to traditional expert based methods (European Landscape Convention, 2000; Swanwick, 2009; Tudor, 2014). Apart from being a cost efficient alternative of generating a large amount of data (See et al., 2016; Eickhoff, 2018), well implemented public participation approaches have been found to increase motivation in scientific topics (cf. Morschheuser et al., 2016; Fritz et al., 2017) and be more inclusive by allowing for heterogeneous groups of participants (Eickhoff, 2018; Bubalo et al., 2019). In addition, results have been found to be on par with traditional expert based methods (Haklay et al., 2010; See et al., 2013). However, the questions of how to motivate users to participate and how to keep participants engaged remain. Gamification has seen widespread adoption and incorporation into various scientific endeavours to address these questions. Gamification - adding playful or gamelike elements to processes - shows increased user motivation (Hamari et al., 2014; Morschheuser et al., 2016), acceptable data quality (Bayas et al., 2016; Bubalo et al., 2019) and the ability to reduce user bias in public participation efforts by including otherwise overlooked demographics (Bubalo et al., 2019).

This chapter will first introduce gamification in geographic information science and how gamification has been adopted in chosen data collection efforts. The chapter will then continue by introducing the requirements elicitation framework used to develop three gamified applications, two of which are introduced here (*StarBorn*, a location-based game I implemented as my MSc thesis (Baer et al., 2019) and *Percy's World*, a location-based game building on the lessons learnt from *StarBorn*). A further application (*Window Expeditions*) is presented in more detail in chapter 4. Finally, this chapter reports on the implementation process and key findings of *StarBorn* and *Percy's World* as well as the implications that arise from the two applications important for further work presented in this thesis.

3.1 Gamification in geographic information science

Geographic information science boasts many successful projects incorporating some level of gamification (cf. Martella et al., 2015; Bayas et al., 2016; Morschheuser et al., 2017; Fritz et al., 2017). Many of these projects focus on collecting or verifying geographic information in Open Street Map (Martella et al., 2015; Fritz et al., 2017), collecting land cover information (Bayas et al., 2016; Fritz et al., 2017) or collecting real-time information such as traffic and navigational data (Martella et al., 2015; Morschheuser et al., 2017). The level of gamification varies considerably from incorporating points and badges to creating location-based games. To explore the level of gamification a list of chosen platforms used in landscape perception research was compiled (cf. Table 3.1). Platforms found in (Bubalo et al., 2019, Figure 1, p. 103) served as a starting point of which a subset was selected and complemented with further gamified platforms found in the landscape perception literature.

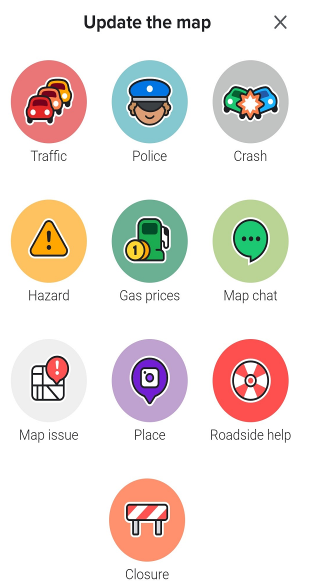
Each platform was inspected according to the level of gamification following the categories in (Morschheuser et al., 2016). The analysed social media platforms (Twitter, Flicker, Instagram) included least gamified elements, merely showing progression in some form (e.g. number of posts). More gamified systems (Geograph, Geocaching and Fotoquest Austria) incorporated some form of point, level or badge system. Points and badges are considered among the most common elements used in gamified systems (Hamari et al., 2014; Morschheuser et al., 2016; Koivisto and Hamari, 2019) and adding leader boards further increases participation by fostering a sense of competition (Hamari et al., 2014; Goh et al., 2017). Highly gamified systems such as Ingress and Pokémon GO include more elaborate features such as storytelling, virtual objects, virtual territories and missions (Sheng, 2013; Colley et al., 2017; Laato et al., 2019a; Jones and Papangelis, 2020).

In addition, the data each platform collects is of interest. This includes data such as demographic information, timestamps, locations, free text contributions, tags, images and ratings. Inspecting the table shows that the data collected through each of the platforms varies considerably. Many of the platforms collect timestamps, tags and in some form free-text to populate the platform with content. Images are also found, however somewhat less common. Demographic information or other data about participants is seldomly collected which is in line with previous findings (See et al., 2016).

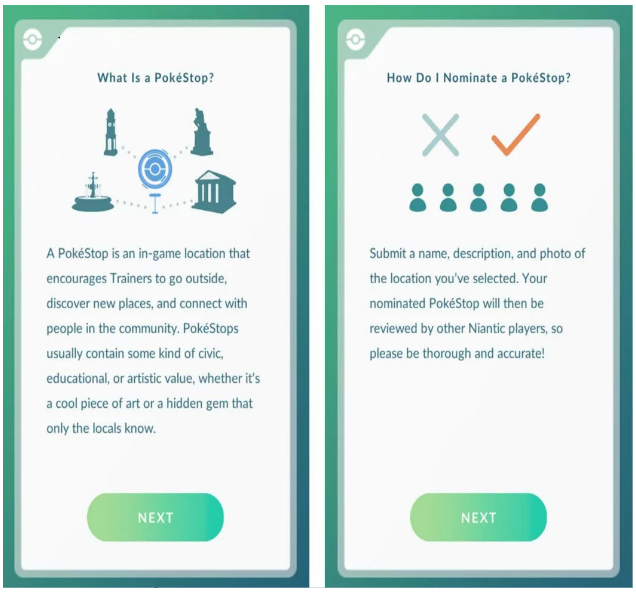
Platform	CT	Points/Scores	Leader boards/Rankings	Badges/Achievements	Levels	Progress	Feedback	Virtual objects/resources	Storytelling	Virtual territories	Teams	Missions	Avatars/Virtual Characters	Data dimensions	Literature
Twitter	P	-	-	-	-	✓	✓	-	-	-	-	-	-	UID, t, ft, {#, l, i}	(Roberts, 2017; Brandt et al., 2017; Brown et al., 2020; Bhatt and Pickering, 2021; Wartmann et al., 2021a)
Flickr	P	-	-	-	-	✓	✓	-	-	-	-	-	-	UID, t, i, {#, ft, l}	(Hollenstein and Purves, 2010; Bordelon and Ferreira, 2017; Figueroa-Alfaro and Tang, 2017; Wartmann et al., 2019; Wartmann et al., 2021a)
Instagram	P	-	-	-	-	✓	✓	-	-	-	-	-	-	UID, t, i, {#, ft, l}	(Van Zanten et al., 2016; Bordelon and Ferreira, 2017; Chen et al., 2018; Niță et al., 2021; Wartmann et al., 2021a)
Geograph	A	✓	✓	✓	-	✓	✓	-	-	-	-	-	-	UID, t, l, ft, #, i	(Chesnokova and Purves, 2018; Seresinhe et al., 2019)
Scenic-or-not	A	-	✓	-	-	-	✓	-	-	-	-	-	-	r, {UID, t, l, ft, #, i}	(Seresinhe et al., 2018; Chang Chien et al., 2021)
Mappiness	A	-	-	-	-	✓	✓	-	-	-	-	-	-	UID, D, t, l, r, {i}	(MacKerron and Mourato, 2013; Seresinhe et al., 2019)
Greenmapper (Hotspotmonitor)	A	-	-	-	-	✓	-	-	-	-	-	-	-	UID, D, t, l, ft, r	(Davis et al., 2016; Bijker and Sijtsma, 2017; Scholte et al., 2018)
Geocaching	P/A	✓	✓	✓	✓	✓	✓	-	-	-	-	✓	-	UID, t, l, ft, {i, r}	(Cord et al., 2015; Balzan and Debono, 2018; Rosário et al., 2019)
Fotoquest Austria	A	✓	✓	-	-	✓	✓	-	-	-	-	✓	-	UID, t, l, i	(Bayas et al., 2016; Fritz et al., 2017; Mccallum et al., 2018)
StarBorn	A	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	-	✓	UID, D, t, l	(Baer et al., 2019; Rauti et al., 2020; Saadeldin et al., 2022)
Window Expeditions	A	✓	✓	-	-	✓	✓	-	-	-	-	-	-	UID, D, t, l, ft, {r}	(Thibault and Baer, 2021)
Ingress	P/A	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	UID, t, l, ft, i	(Colley et al., 2017; Laato et al., 2019a)
Pokémon GO	P/A	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	UID, t, l, ft, i	(Colley et al., 2017; Laato et al., 2019a)

Table 3.1: Table showing the number of gamified elements per platform. **Crowdsourcing type (CT):** *passive (P), active (A)*; **Data dimensions:** *Unique user IDs (UID), demographic information (D), timestamp (t), location (l), free text (ft), tags (#), images (i), ratings (r), other (o)*

Academia has expressed caution towards adopting gamification in landscape perception research, potentially due to gamification being a rather young domain with only a small number of well-established frameworks and limited unified terminology (Hamari et al., 2014). However, recent years have seen a massive increase in research interest (Koivisto and Hamari, 2019). The private sector on the other hand has embraced the potential of gamification to engage people and increase motivation which is reflected in applications such as Waze (Morschheuser et al., 2019), Ingress (Morschheuser et al., 2017; Laato et al., 2019a; Laato et al., 2019b) and Pokémon GO (Colley et al., 2017; Laato et al., 2019a; Laato et al., 2019b). These have successfully motivated hundreds of millions of people to participate as well as contribute data. Waze for example focuses on traffic and road related data whereas Ingress and Pokémon GO focus on features with "civic, educational or artistic value" (cf. Figure 3.1). Even though only a small percentage of users contribute data, due to the unprecedented number of users, these applications have generated enormous amounts of spatial information (cf. Laato et al., 2019a). These non-academic platforms are therefore prime examples of using gamification to motivate participation and contributions. However, contribution locations have been found to be biassed towards wealthier areas with higher levels of education, whereas areas of minorities are underrepresented (Colley et al., 2017; Juhász and Hochmair, 2017) raising questions of inclusiveness and access.



(a) Contributing to Waze



(b) Contributing to Pokémon GO

Figure 3.1: Screenshots of contribution possibilities in Waze and Pokémon GO

Seeing the high popularity of applications and games from the private sector, there have been efforts to bridge the gap between the private and academic sectors. The *Massive Multiplayer Online Science (MMOS)* initiative has successfully integrated crowdsourcing in highly popular games such as Eve Online[1] and Borderlands 3[2] to address scientific questions (cf. Marx, 2015; Peplow, 2016), albeit not geographic in nature. Shifting our gaze back to academia, one of the most successful gamified crowdsourcing platforms designed to collect information about navigational decisions is *Sea Hero Quest*, an application to collect data on people's spatial abilities in a virtual game world (cf. Coutrot et al., 2018a; Coutrot et al., 2018b). The game was developed in collaboration with various private and academic companies and institutes. *Sea Hero Quest* boasts millions of contributions and underlines the potential of highly gamified solutions to produce a large amount of high quality data to be used in geographic information science.

Using the compiled list of platforms as well as reviewing relevant literature in crowdsourcing and gamification, I set out to develop and implement a number of applications geared towards the collection of landscape relevant data. In a first step I define the overarching requirements which inform the further development and implementation.

3.2 Requirements elicitation framework

The success of an application is typically measured as how well it meets its intended purposes (Nuseibeh and Easterbrook, 2000). Thus, defining initial requirements is a crucial first step towards ensuring a successful implementation (Kotonya and Sommerville, 1998) and is an important part of exploring stakeholders' needs to define specific purposes (Nuseibeh and Easterbrook, 2000; Carrizo et al., 2014). Requirements vary depending on the domain and audience of an application and different requirements become important in spatial as opposed to aspatial applications (Jones and Papangelis, 2020). For example, in active spatial crowdsourcing platforms and location-based games, location-based capabilities, geographic information visualisation and location obfuscation become important.

[1] www.eveonline.com (accessed: 15.08.2022)
[2] www.borderlands.com (accessed:15.08.2022)

Seeing the general goal is to implement and analyse gamified crowdsourcing applications to collect high-quality in-situ landscape related contributions, I pursue a twofold strategy of requirement elicitation:

Data requirements elicitation: Where it is important to identify and define the type of data which should be collected using the application.

Feature requirements elicitation: Where state-of-the-art application and game design approaches are adopted and discussions of user motivation and retention become important.

In a first step I use the framework of Carrizo, Dieste and Juristo (Carrizo et al., 2014), which "help[s] requirements engineers select the most adequate elicitation techniques at any time" (Carrizo et al., 2014, p. 644). The framework entails rating various attributes and values out of the perspectives of multiple stakeholders to identify and select the most fitting requirement elicitation techniques for a given project. The elicitor (cf. Carrizo et al., 2014) is defined as the researcher tasked with conducting the elicitation sessions whereas the informants (cf. Carrizo et al., 2014) are defined as colleagues associated with this thesis. Following (Carrizo et al., 2014), each attribute is given a respective value (cf. Table 3.2).

The framework identifies questionnaire, brainstorming and prototyping as most suited elicitation techniques, which is in line with the literature (cf. Bernhaupt et al., 2007; Prandi et al., 2015; Jones et al., 2017; Jones and Papangelis, 2020). Since the application is academic in nature, the questionnaire is replaced by a thorough literature review (cf. Chapter 2).

Brainstorming: Multiple brainstorming sessions are performed to come up with ideas, key concepts and features.

Prototyping: Ideas and concepts are implemented as prototypes to explore key features and user motivation.

Through reviewing contemporary literature (cf. Chapter 2) I identified key data requirements (cf. Table 3.3). The applications should collect demographic information as well as spatial information on where contributions are made. In addition, the applications should focus on generating landscape specific contributions whilst allowing for multiple contributions of the same location and having a broad spatial coverage.

Factor	Attribute	Value	Description	Questionnaire	Brainstorming	Prototyping
Elicitor	Training in elicitation techniques	*mixed*	The elicitor has zero to high formal education and practical training	✓	✓	✓
	Elicitation experience	*mixed*	The elicitor has $<$ 2 elicitation projects to 2 – 5 elicitation projects depending on technique	-	✓	✓
	Experience with elicitation techniques	*mixed*	The elicitor has zero to low experience with elicitation techniques (0 – 5 projects)	✓	✓	✓
	Familiarity with domain	*high*	One project carried out and considerable formal knowledge acquired	✓	✓	✓
Informant	People per session	*group*	2 – 5 people per elicitation session	✓	-	-
	Consensus among informants	*high*	Consensus	✓	-	✓
	Informant interest	*high*	Informants are interested in participating in elicitation session	✓	✓	✓
	Expertise	*knowledge-able*	Informants have 2 - $>$10 years of experience in the domain	✓	✓	✓
	Articulability	*high*	Informants explain knowledge very well	✓	✓	✓
	Availability of time	*high*	The informants do not have a time limit for elicitation sessions	✓	✓	✓
	A Location / accessibility	*near*	Informants and elicitor belong to the same research group and are thus near	✓	✓	✓
Domain	Type of information to be elicited	*tactical*	The goal is to elicit processes and functions	✓	✓	✓
	Level of available information	*lower*	Basic knowledge (concept) available through literature review	✓	✓	✓
	Problem definedness	*high*	The problem is well defined through research gaps	✓	✓	✓
Process	Project time constraint	*low*	The project does not have hard time constraints	✓	✓	✓
	Process time	*start / middle*	The project is at the start thus elicitation of general definitions	✓	-	✓

Table 3.2: Table showing most adequate elicitation techniques according to (Carrizo et al., 2014). Columns of less suitable elicitation techniques were omitted.

	Requirement	Data Type	Reasoning	Literature
User Info	User identifier	*Text*	To identify individual users	
	User demographics	*Text*	To analyse differences within and between demographic groups	(See et al., 2016; Bubalo et al., 2019)
Contributions	Landscape data	*Ratings / Text*	To analyse how individuals experience or perceive their surroundings	(Derungs and Purves, 2014; Derungs and Purves, 2016; Aiello et al., 2016; Chesnokova and Purves, 2018)
	Contribution location	*Area / Cell*	To display contributions and analyse contributions according to their location. An area or cell is used to comply with data protection through obfuscation	(Duckham and Kulik, 2005; Kearney et al., 2008; Díaz et al., 2010; Ross, 2012)
Coverage	Multiple contributions of same location	*Contributions*	To analyse intra-user and intra-location similarities and differences	(Haklay et al., 2010)
	Broad coverage	*Contributions*	To analyse spatial variance	(Fritz et al., 2017; Bubalo et al., 2019)

Table 3.3: Table showing the data requirements of the application.

In addition to the data requirements I identified four key gamification elements influencing user motivation:

Competition: Competition has been stated as a crucial motivational incentive increasing user enjoyment as well as participation (Morschheuser et al., 2019) and has been found to increase data quality in crowdsourcing efforts (Eickhoff et al., 2012; Morschheuser et al., 2017).

Collaboration: Allowing for and fostering user collaboration through cooperative elements and incorporating social features increases motivation (See et al., 2016; Fritz et al., 2017; Morschheuser et al., 2017; Morschheuser et al., 2019) as well as the probability of a user recommending the application (Morschheuser et al., 2019).

Exploration: Applications facilitating exploration of a virtual and/or physical environment have been found to increase user motivation (Wang and Sun, 2011; Brich, 2017) and have been successful at changing users' behaviours (Liu et al., 2011; Colley et al., 2017). This effect is especially prominent in location-based games where users explore new areas of a city as in GeoCaching (Liu et al., 2011) or users actively change their route or mode of transport as has been observed in Pokémon GO (Colley et al., 2017).

Progression: Creating a sense of progression can have a positive effect on user satisfaction, increasing engagement (Wang and Sun, 2011). Most important in terms of user progression are virtual rewards such as points, badges and rankings which are often comparable and communicable (Hamari et al., 2014; Goh et al., 2017).

The identified data and feature requirements guide the implementation of three gamified spatial crowdsourcing applications geared towards landscape data generation. In the following, two of these applications are presented which should be considered as pre-studies. In (cf. Chapter 4) I then present the third application which constitutes a major part of this thesis' data and results.

3.3 *StarBorn*: a location-based game for landcover data generation

StarBorn is the name of an application I implemented as part of my MSc thesis (Baer et al., 2019) to complement remotely sensed land cover data acquisition through a location-based game. The primary goal of the application was to allow non-expert users to contribute in-situ land cover judgements according to a predefined list. The generated data was analysed and compared to an authoritative dataset. This section is largely based on the published peer-reviewed paper (Baer et al., 2019) and touches upon the implementation process and highlights key findings.

Remotely sensed land cover products are important datasets in policy and decision making processes on various scales (Lambin et al., 2001; Foody et al., 2013; Sexton et al., 2015). However, various products show considerable disagreement in land cover types at given locations (See et al., 2013; Sexton et al., 2015). This calls for novel methods of data quality and reliability assessments (cf. Bayas et al., 2016). In-situ land cover classifications are thus particularly valuable datasets. However, high quality in-situ land cover datasets with broad coverage remain scarce. Crowdsourcing shows potential in generating such datasets, especially when adding gamified elements to increase user motivation (Bayas et al., 2016). However, questions regarding the viability of using a gamified application to crowdsource in-situ land cover judgements and how the generated data compares with an authoritative dataset remain.

To address these questions and shortcomings, I implemented *StarBorn*. Users were first presented with the game's backstory after which they were asked to register and report limited demographic information such as age and gender. After creating an appropriate avatar (cf. Figure 3.2) users chose a team, strengthening the cooperative as well as competitive elements of the location-based game (cf. Morschheuser et al., 2017; Morschheuser et al., 2019). Users were informed that the contributed data would be used in a research context.

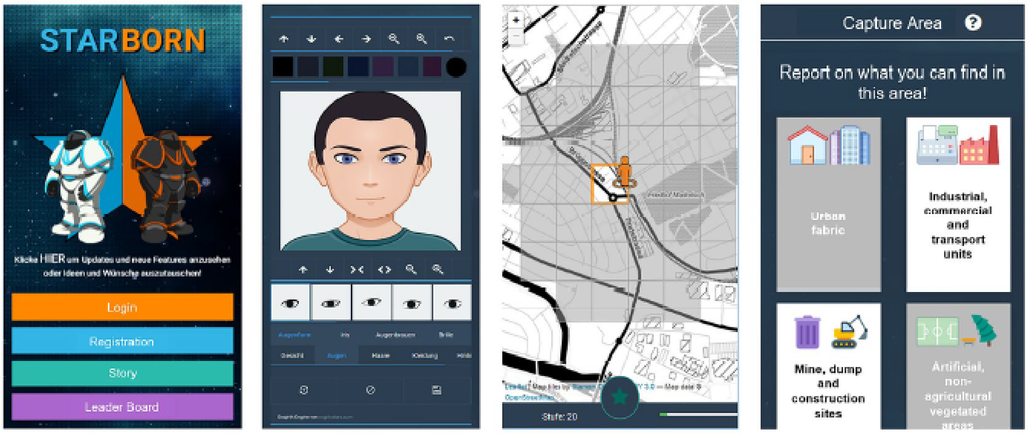


Figure 3.2: Screenshots of StarBorn (Baer et al., 2019)

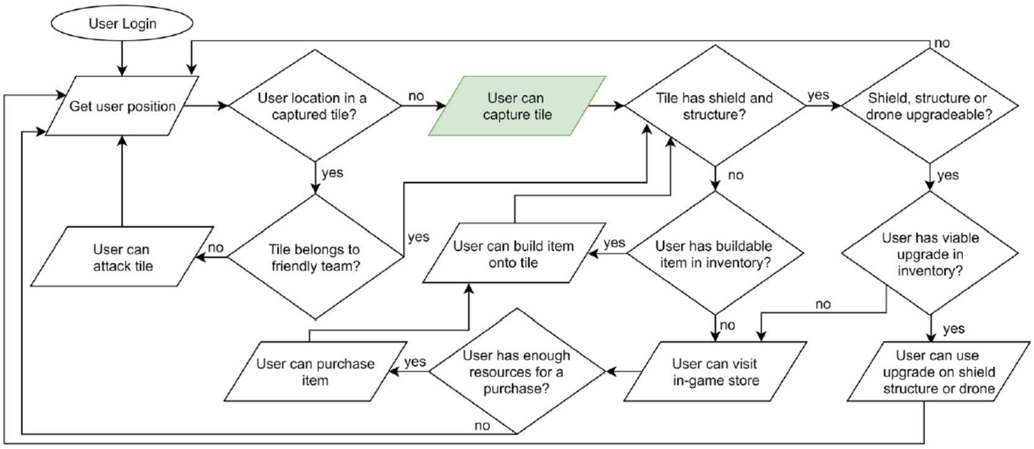


Figure 3.3: Flowchart of user decisions in StarBorn (Baer et al., 2019)

Once registered, users could capture real-world locations for their team by classifying the landcover of their immediate surroundings from a predefined list (cf. Figure 3.2) on a fixed grid of 200 x 200m cell size in Switzerland. Areas belonging to the enemy team could be attacked and conquered. Users were rewarded with experience points and gradually unlocked various in-game features, earned badges and titles and a leader board showed the top performing players. The key player decisions are summarised in the flowchart (cf. Figure 3.3).

Over the course of around three months 138 users registered of whom 84 contributed at least once. User reported years of birth were mostly between 1987 and 2003 (min = 1954; max = 2016; mean = 1989) and gender was heavily biassed towards male participants (male = 62, female = 16, not reported = 6). *StarBorn* successfully generated 13319 contributions in 11364 unique locations (of which 936 show multiple contributions), corresponding to 533km^2 of classified area. Most locations were classified as being either urban ($n = 8010$) or industrial ($n = 7724$) areas with water ($n = 1166$) and green area ($n = 1065$) being least common. The results showed significant ($p < 0.01$) correlations between number of contributions and between user agreement rates of the land cover type in a specific location. This indicates the validity of Linus' Law (Haklay et al., 2010) in the generated dataset, which states that "given enough eyeballs, all bugs are shallow" (Raymond, 2001, p. 19) or in other words, if more people contribute the overall quality increases (Haklay et al., 2010).

I was particularly interested in how the dataset generated through a location-based game with non-expert users compared to an authoritative land cover dataset. I compared the crowdsourced data with the CORINE 2012 land cover product (cf. European Environment Agency, 1994) and found a relatively high agreement rate (76.3%) between the authoritative dataset and any of the reported land cover classes per contribution. However, the results show a significantly negative correlation between the number of contributions of an individual user and the agreement rate of their contributions with the authoritative dataset ($p < 0.01$). The decline in agreement rate with increasing contributions can arguably be attributed to users maximising their in-game performance, hinting that future implementations should have safeguards against incorrect contributions, for example through moderation.

To delve deeper into the comparison of *StarBorn* and CORINE, a subset of contributions where users reported one land cover type was created and a confusion matrix was calculated (cf. Figure 3.4). The results of this subset showed an overall accuracy of 68.6% which is mostly due to the high agreement rates of the frequent land cover classes urban, industry, arable and forest. However, noteworthy differences can be identified. Major confusions include pasture with arable (64.6%), no vegetation with shrub (56.7%), industry with urban (33.6%) and pasture with shrub (12.8%). These confusions underline that "it is important to consider and test for potential variations in the way that landscape features are labelled and conceptualised by different groups of contributors when analysing crowdsourced data" (Comber et al., 2016, p. 16). Thus, it becomes important to consider how different people perceive their surroundings and what this implies for future policy and decision making processes. More information on the implementation and the results can be found in the open access paper (Baer et al., 2019).

3.4 *Percy's World*: a location-based game for landscape data generation

Building on the lessons learnt from developing, implementing and analysing *StarBorn*, I set out to develop a gamified application geared towards capturing rich natural language descriptions of landscapes, going beyond reporting predefined categories. The results of analysing data generated with *StarBorn* showed that even for

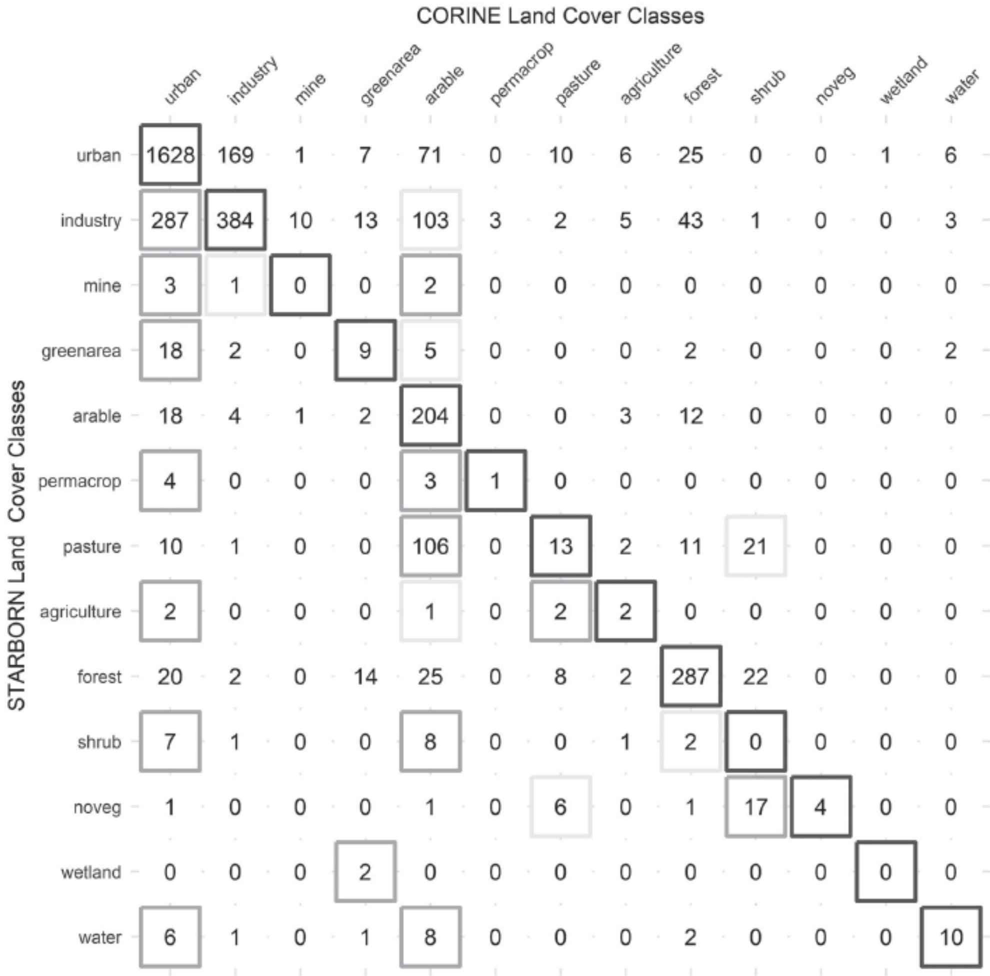


Figure 3.4: Confusion matrix comparing CORINE and StarBorn landcover classifications (Baer et al., 2019)

a relatively small list of 13 predefined land cover categories, people often disagree. This highlights the importance of understanding people's varying perceptions of their surroundings and calls for rich datasets from which we can extract perceptions. How people conceptualise and talk about or describe their surroundings also varies (cf. Burenhult and Levinson, 2008; Putten et al., 2020), potentially giving insights into how environments are valued and perceived. Natural language has been found to be a potential proxy of understanding individuals' perceptions of landscapes (cf. Burenhult and Levinson, 2008; Derungs and Purves, 2014; Bieling, 2014; Koblet and Purves, 2020; Wartmann et al., 2021b). Therefore, the envisioned application should aim at capturing how people describe their surroundings to build and analyse a rich corpus of natural language landscape descriptions.

In a first step, I conducted three brainstorming sessions with 2 - 3 people each with the goal of linking data and gameplay requirements to a feature rich conceptual game whilst keeping lessons learnt from *StarBorn* in mind. Brainstorming is a widely used technique in requirements elicitation (Carrizo et al., 2014), iterative design (Dow et al., 2005) and ideation (Jonson, 2005) and has been used in similar projects (cf. Paay et al., 2009; Prandi et al., 2015). The three brainstorming sessions of 30min – 120min in duration were successful at linking the presented requirements (cf. Table 3.4) and establishing a conceptual location-based game. The original concept of the location-based game merged game features from the well-known games *Siedler von Catan* (capturing territories and resource generation), *Risk* (conquering areas), *Starcraft* and *Satisfactory* (energy management), *Pokémon GO* (location-based battles and rewards), *Ingress* (team based collaboration) and *World of Warcraft* (concepts of player versus player (PvP) and player versus environment (PvE)). Within the brainstorming sessions, sketches of core mechanics were drawn out, discussed and iterated upon (cf. Figure 3.5).

Figure 3.5: Brainstorming Percy's World

The resulting game concept envisioned a game where players were divided into two opposing teams fighting over virtual game tiles at real world locations. After sketching out the core game mechanics and features, and linking the data requirements with the game feature requirements, I continued with a multistage prototyping approach. I identified three prototyping stages which were viable within the scope of our project:

Board game prototyping: To explore core game mechanics and playability (Jones et al., 2017).

Paper prototyping: To test individual game page mock-ups and investigate the data contribution pipeline by analysing different question formulations (Snyder, 2003).

Software prototyping: To test client-server interactions, basic screen layout and underlying map visualisations (Ollila et al., 2008).

Game Feature	Game Req.	Data Req.	Reasoning
User system	cp, cb, ex, pr	ui	Individual users must be identifiable to analyse data on the granularity of individual users.
Tutorial	pr	ud	Introducing players to core concepts and mechanics is important in a crowdsourcing context (Foody et al., 2013; Bayas et al., 2016) and in complex game playing environments (Andersen et al., 2012).
Home base system	pr	cl	Having a proxy for an individual's most important locations is important when asking questions revolving around local vs non-local knowledge (Díaz et al., 2010; Ross, 2012).
Capturing game tiles	cp, cb	ld, cl, bc	Capturing game tiles proved as a viable game mechanic (Baer et al., 2019).
Build on game tiles	cb	mc, bc	Building on game tiles proved as a viable game mechanic (Baer et al., 2019).
Team play	cp, cb	mc, bc	Team play fosters collaboration and has a positive effect on the probability of users recommending the application (Morschheuser et al., 2019).
Conquering areas	cp, cb, ex, pr	ld, cl, mc	Having multiple classifications coming from different users at the same location is crucial to be able to compare intra-location variability (Haklay et al., 2010).
Temporal rankings	cp	ld, mc, bc	Having constrained timeslots for competitive elements has been found to boost contributions (See et al., 2013) and user retention (Eickhoff et al., 2012)
Narrative	cp, cb, pr	-	It is important to not only include badges or leader boards but also other game mechanics to make the application fun (cf. Liu et al., 2011; Hamari et al., 2014; Morschheuser et al., 2017; Koivisto and Hamari, 2019)
Special events & locations	cp, cb, ex	ld, cl, mc, bc	Using special events at specific locations can motivate users to visit specific locations (cf. Colley et al., 2017) ultimately increasing overall number of contributions.
Level system	pr	-	Incorporating a level system increases users' sense of progression and results in higher user satisfaction (Wang and Sun, 1995)
Achievements	pr	-	Achievements lead to higher user involvement (Hamari et al., 2014) and since they are communicable rewards (Goh et al., 2017) they arguably lead to increased competition.

Table 3.4: Table showing how presented requirements are linked. **Game requirements:** *competition (cp), collaboration (cb), exploration (ex), progression (pr)*; **Data requirements:** *user identifier (ui), user demographics (ud), landscape data (ld), contribution location (cl), multiple contributions of the same location (mc), broad coverage (bc)*

The literature states using 5 users for prototyping applications is a viable number of participants (Nielsen, 1993; Maisonneuve and Chopard, 2012) however arguments have been made that incorporating 5 – 20 participants greatly increases feedback and detection of flaws and errors (Faulkner, 2003). This is in line with other findings stating that 5 – 15 contributions are needed to achieve optimal quality and where increasing the number of contributions merely increases effort needed and not quality (Goodchild and Li, 2012). These considerations led to recruiting at least a total of 5 participants for each prototyping stage.

3.4.1 Prototyping

The first prototyping sessions revolved around board game prototyping. The goal was to test three hypotheses regarding the core game mechanics:

H1: The competitive (capturing, attacking and conquering) and collaborative (building on and guarding areas) elements are engaging and sufficiently motivate participants to play.

H2: Attacking enemy areas and capturing free areas is incentive enough for participants to explore the game field.

H3: Collecting and managing various resources is motivating and leads to strategic thinking.

After creating relevant board game material, I conducted three prototyping sessions (3 Female, 6 Male; ages 24 – 59; written consent given). The sessions revealed the core game mechanics to be fun and engaging and all participants mentioned they enjoyed the game. The competitive elements such as attacking the enemy team or attacking a non-player character as well as the collection of resources were frequently mentioned as particularly engaging. One participant proposed having resources of varying rarity would make the resources more interesting. The collaboration and teamplay elements were also mentioned as motivating and strategic decision-making processes were considered as especially stimulating. However, participants also mentioned the high reliance on chance to have a negative impact on their motivation and it was mentioned that the game started to lose its appeal for both teams once one team secured a considerable lead. Multiple participants also mentioned the lack of incentives to visit unexplored game-tiles and stated the significance of space was not emphasised enough. They proposed incorporating some form of exploration or mystery element where users are rewarded for being the first user to visit a tile or some form of location-based ranking system. Two participants also proposed having resources be more linked with the current area of a player (e.g. land cover dependent resource distribution).

These findings suggest hypothesis one (H1: competition and collaboration are motivating) to be true. Hypothesis two (H2: no further incentives are needed for players to explore the game field) on the other hand was found to be false calling for special consideration of additional incentives for users to explore their surroundings in future implementations. Hypothesis three (H3: resource collection and management is motivating) was found to be partially true where the resource management was reported to be engaging but could be made more interesting.

Figure 3.6: Board game prototyping Percy's World

Interestingly, I observed some additional noteworthy behavioural characteristics of how the participants approached the gameplay providing valuable insights into how users might engage with the finished application. Players started on an empty game field (no captured areas) with a number of non-player characters in the centre of the game field. Without any instructions, all participants started to converge towards these central "landmarks" and would choose to start capturing areas in the vicinity of these. Once multiple areas were captured and players started attacking each other's areas, the mind-set changed and participants would start to retreat to the outskirts of the game area to make it more difficult for the enemy team to reach them. This is an important observation as in the final location-based game I expect to see frequented areas such as central urban areas to be captured rapidly and players to then gravitate towards the periphery. Clusters of increased gameplay were also observed in *StarBorn* (Baer et al., 2019). Another key observed behaviour was that as the game progressed participants started conversing within their team and actively discussed potential strategies of future moves. Seeing the importance of being able to communicate with team members, communication was added as a requirement of the software prototype.

3.4.2 Implementation

After successfully conducting board game prototyping sessions and collecting feedback, I started work on implementing the base mechanics of the location-based game *Percy's World*. Key shortcomings of the core game mechanics and potential improvements which were identified in the feedback of the board game prototyping sessions as well as observed behaviours were taken into consideration in the implementation of the software prototype. The goal was to have a working software prototype with minimal features to start iterative testing and development.

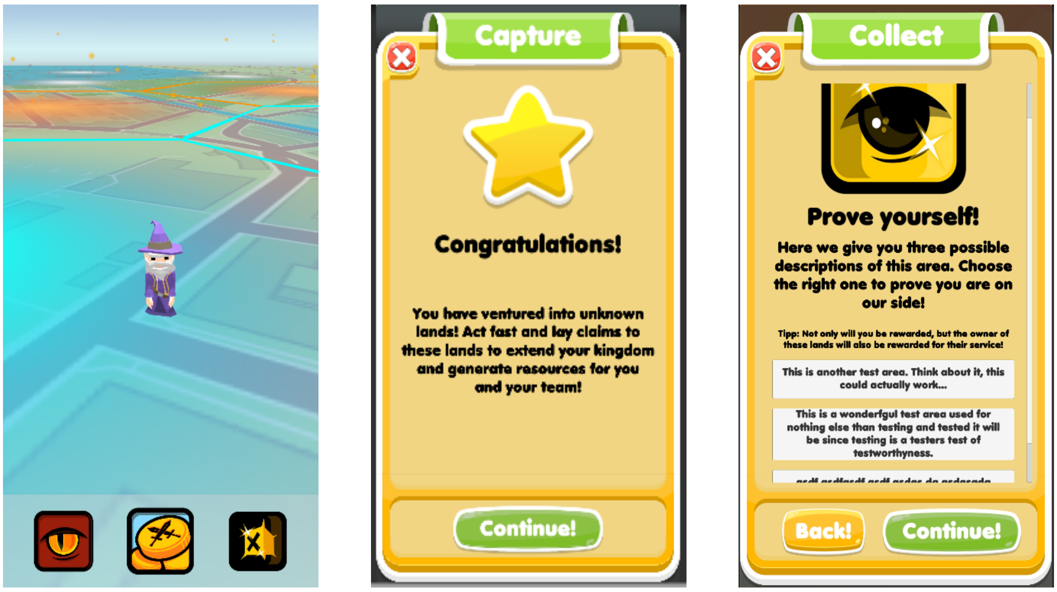
To implement the game I chose Unity[3] - a cross platform game engine - as the development environment. Unity stands out as a development platform seeing it is free to use for small projects and applications can easily be compiled for multiple platforms such as Android and IOS. In addition, Unity boasts a large library of plugins and the application can be written in C#. The implementation was split into four stages: remote code, client-server interactions, client backend code and client frontend. The remote code was implemented on ChilliConnect[4] and encompassed all logic running in the cloud. This included all processes where code input and execution must be trusted such as encrypting and saving user information and executing cheat-protected code such as distributing rewards and capturing territories. Client-server interactions were implemented through the development of an application programming interface (API) where the server listened for specific commands from a client, ran appropriate code and returned the results to the client, which triggered respective events. For example, when a player captured an area the client sent the server all needed information, the server checked if all requirements for capturing are fulfilled and if yes, returned a random reward to the client, which triggered the success screen in the client. Since client-side code can be manipulated, the client backend code only included processes that had no influence on player progression. This included systems that built the game world or moved a player's avatar. Finally, the client-frontend code handled mostly aesthetic and visual processes in the user interface such as triggering appropriate events on button clicks or displaying the players inventory.

Since *Percy's World* was a location-based game, considerable effort went into the spatial aspects of the application and how to represent real world information as a virtual environment. I added spatial capabilities to Unity through the MapBox[5] software development kit (SDK). To build the game world, a player's current location was read from the global positioning service of their device. Once their position was identified, respective map tiles with custom styling were downloaded from MapBox

[3] www.unity.com (accessed: 17.05.2022)
[4] www.chilliconnect.com (accessed: 17.05.2022)
[5] www.mapbox.com (accessed: 17.05.2022)

and displayed showing a player's position and surroundings. In addition, the current player's location was transformed to a global hexagonal grid index using H3[6]. This hexagonal grid index was used to retrieve game relevant information from the server which in return was used to overlay the base map tiles with hexagonal game tiles (cf. Figure 3.7). These were populated with game relevant information such as which team an area belongs to and if an area has any defensive structures. The map tiles as well as the hexagonal game tiles were cached as to minimise bandwidth and were only recalculated on player interactions with a game tile or if a player moved into a new game tile. In line with the core mechanics of location-based games, players had to move in the real world to play the game which was achieved by only allowing interactions with the game tile a player was located in.

Unfortunately, the software prototype was never finished nor tested due to the emergent global pandemic which forced many countries into lockdown or other forms of restrictions. Seeing the official guidance was to minimise social contacts and adhere to the social distancing rules it became impossible to test the newly implemented location-based game prototypes. Thus, work on the location-based game was discontinued in favour of a new platform: *Window Expeditions* (cf. Chapter 4).



(a) Percy's World screenshot (b) Percy's World capture (c) Percy's World collect

Figure 3.7: Screenshots of Percy's World

[6]https://eng.uber.com/h3/ (accessed: 17.05.2022)

3.5 The global pandemic

The imposed restrictions due to the global pandemic led to the discontinuation of the location-based game *Percy's World*. However, the extraordinary circumstances of the pandemic also led to interesting new developments in terms of gamification and landscape research. The global Covid-19 pandemic dramatically changed our experiences of and interactions with our immediate surroundings through various non-pharmaceutical interventions such as restrictions, social distancing measures and lock-downs (cf. Flaxman et al., 2020; Lai et al., 2020). People's everyday mobility was particularly affected which is reflected in the shift towards significantly more time spent in residential areas and a decrease in visitations of grocery stores and restaurants (Lee et al., 2020; Elarde et al., 2021; Lucchini et al., 2021). During the pandemic an increase in the use of local outdoor spaces such as urban green areas and urban gardens was observed (Venter et al., 2020; Ugolini et al., 2020; Baumeister et al., 2022) where access was not limited due to restrictions or socioeconomic factors (Ugolini et al., 2020; Uchiyama and Kohsaka, 2020).

In addition, many were encouraged to work from home, considerably increasing the time spent at home. During this time of emergent borders and changing accessibility, various playful approaches crystallising around these new limitations were observed. These ranged from balcony concerts to hiding teddy bears in windows (for an overview, see (Thibault and Baer, 2021)). In addition, people started to rediscover their immediate surroundings such as their gardens (Thibault and Baer, 2021), which is highlighted in the BBC interview excerpt (cf. Example 3.1).

The extraordinary circumstances also led to a surge of digitalisation (De' et al., 2020; Oldekop et al., 2020; Amankwah-Amoah et al., 2021). Many events that would usually be in person such as conferences, presentations and meetings were conducted digitally. Various recreational activities were also moved to the virtual space (cf. Haqq and McCrickard, 2020; Morse et al., 2021; Haqq et al., 2021) which is reflected in the increase of video game consumption (Lemenager et al., 2021; Xu et al., 2021). However, the benefits of this accelerated digitalisation must be taken with a grain of salt as it may also contribute to an increasing digital divide, the inequality of access to digital media (De' et al., 2020; Cheshmehzangi et al., 2022).

Example 3.1:

"(M): We couldn't be more different in terms of content in this next conversation Conol and Braiden a father and son 45 and 11 years old. They're in lockdown together with their family in Belfast. Conol is a science teacher and also a Duke of Edinburgh awards leader and hill walker. He and his wife Joslyn have three kids and there's Pat the dog as well. Braiden's in his last year of primary school, he likes gaming, gaelic football, soccer and myths and legends and art and I put my money on him going quite some way in life, if this is where he's at already.

(B): One of my favourite things to do in lockdown is just go to my bedroom window and stare out it for like half an hour and just piece things together and think about things that's [sic] happening.

(C): I mean you have a pretty good view of the park and the trees from your bedroom window. Are you talking about that or are you talking about just big life stuff?

(B): A bit of both, uh, there's a pair of smaller binoculars that I look through the window at and I find birds and just as I am saying that I can see a massive bird out the window and I think, oh, no, yeah. . .

(C): I'm still delighted we saw that goldcrest. That has been one of the absolute highlights of lockdown was you and I sitting in the deck chairs that day beside the rose bush and this goldcrest coming flying out of the Fusia and landing on the rosebush beside us and spending the next twenty minutes trying to chase it whilst not moving to scare it off."

(BBC listening project released on 07 Jun 2020)

3.6 Implications for further work

The two highly gamified applications presented in this chapter (*StarBorn* and *Percy's World*) led to the following implications for the work presented hereinafter:

1. Gamification has the potential of engaging a high number of participants and can lead to many high quality contributions. However, special attention must be paid to how the crowdsourcing task is formulated and what data is to be collected. In particular, questions regarding the depth of data generated through predefined categories become important and exploring richer forms of contributions such as natural language descriptions shows potential.

2. Working on the location-based games presented above highlights the importance of requirements elicitation and prototyping to identify essential features and test key mechanics to collect relevant data. Especially important is identifying gamification elements which are suited to increase participants' motivation for a specific crowdsourcing task.

3. The extraordinary circumstances caused by the global pandemic underline the importance of exploring new avenues of active crowdsourcing in times of restricted access and limited social contacts.

4. The reduced mobility has potentially led to increased appreciation of our immediate surroundings, however, how we perceive our everyday lived landscapes needs further consideration.

4 Implementing Window Expeditions

> *Stuff your eyes with wonder, he said, live as if you'd drop dead in ten seconds. See the world. It's more fantastic than any dream made or paid for in factories.*
>
> — **Ray Bradbury**
>
> (Author)

The environments and landscapes where we spend most of our lives are underrepresented in landscape perception research in favour of scenic or idealised landscapes (cf. Beza, 2010; Menatti and Da Rocha, 2016; FOEN, 2020). However, it is important to understand how everyday lived landscapes are perceived to work towards fair policies and inclusive planning (Antrop, 2005; Bubalo et al., 2019). The importance of our immediate surroundings became especially evident during the global Covid-19 pandemic where various emergent regulations greatly changed individual daily mobility (cf. Borkowski et al., 2021). This led to an increased use of close-by infrastructure such as urban greenspaces (cf. Venter et al., 2020; Ugolini et al., 2020; Baumeister et al., 2022) and "staycations", short distance vacations in favour of long distance journeys (Lin et al., 2021). This shift of increased time spent in close proximity to the place of residence and the under-representation of these areas in landscape perception research calls for novel approaches of investigating our more immediate surroundings. Has the global pandemic sparked a rediscovery of the near? Can we debunk the apocryphal assumption that our everyday lived landscapes are mundane by collecting and analysing a corpus of in-situ natural language landscape descriptions?

During the first wave of the pandemic and the resulting first lockdowns, work on *Percy's World* was paused and new ideas of replacing the intended location-based game were discussed. In further brainstorming sessions with colleagues as well as discussions at an international gamification conference (GamiFIN2020) ideas of conducting active crowdsourcing during times of increased restrictions were collected. An opportunity to implement an active crowdsourcing platform emerged that capitalised on people spending more time at home in combination with an accelerated digitalisation of work and leisure. Building upon the key findings of implementing the two highly gamified applications presented in the previous chapter (cf. Chapter 3) and complementing these with literature from traditional participatory approaches of spatial data collection, I implemented a further application called *Window Expeditions*. This application was implemented to collect landscape descriptions of the places where people lived. The primary goals were to reduce the feelings of isolation during lockdown and quarantine as well as to build a multilingual corpus of in-situ landscape descriptions. In the following the development and testing processes are presented and key implementation steps are discussed. This chapter first presents an overview of the key requirements of the application. In the subsequent sections this chapter discusses how the main features of *Window Expeditions* were implemented using a popular framework. Lastly, this chapter highlights how the application was tested and promoted.

4.1 Requirements

In the previous chapter, the main requirements for an application aiming to capture how people perceive landscapes were identified as collecting demographic information as well as landscape relevant information including the location of contributions (cf. Chapter 3). These underlying requirements were adjusted and extended to take the extraordinary circumstances of the global pandemic into account. The resulting requirements for *Window Expeditions* were defined as follows.

The application:

- ... should use gamification to provide an enjoyable experience of sharing everyday lived landscapes
- ... should facilitate the collection of landscape descriptions as unstructured natural language in form of texts
- ... must adhere to contemporary data protection and privacy regulations
- ... must ensure the safety of participants during the extraordinary times of the global Covid-19 pandemic by allowing contributions from home
- ... should collect basic demographic information and allow for contributions in multiple languages from anywhere on the earth

4.2 *Window Expeditions'* mechanics, dynamics and aesthetics

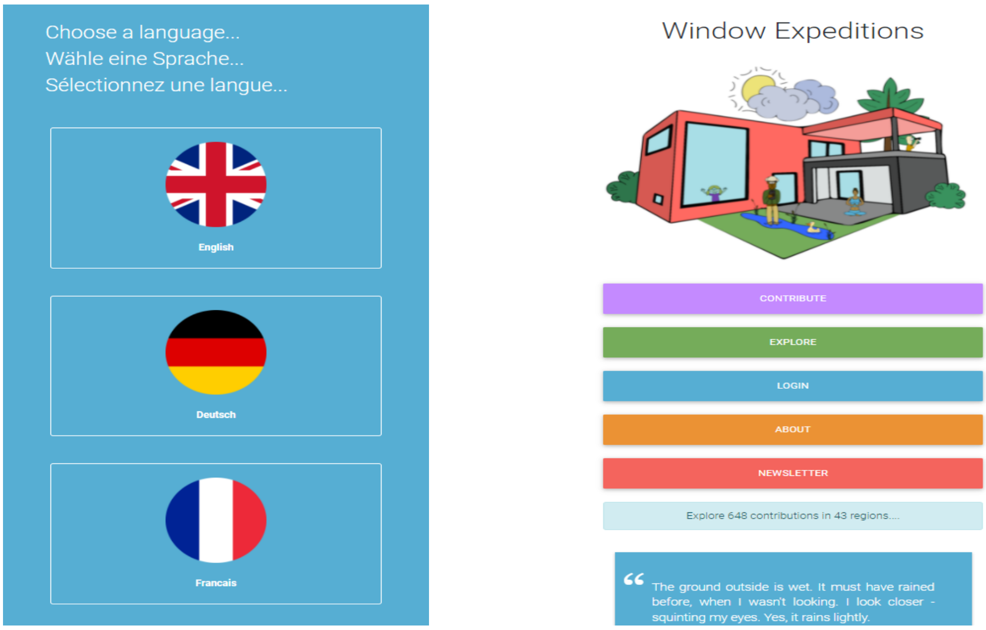
After collating the presented list of requirements the literature was consulted to explore potential frameworks to guide the implementation process. Since *Window Expeditions* was tailored towards user participation, taking both the users' as well as the designers' perspectives into consideration was particularly valuable. As such, the MDA framework (cf. Chapter 2) was used as an underlying guiding structure for the implementation.

Window Expeditions was built from scratch as a web-application in three languages (English, German and French) (cf. Figure 4.1a) and allows users to explore and contribute in-situ natural language landscape descriptions (cf. Figure 4.1b). The three main features of the application include contributing in-situ natural language landscape descriptions (cf. Figure 4.4), exploring landscapes through textual descriptions (cf. Figure 4.5) and moderating the user generated content (cf. Figure 4.10). Firstly, the application motivates users to contribute descriptions of their immediate surroundings (preferably from home) either as registered users or anonymously. Users are rewarded with points for each contributed landscape description after approval by the moderation team. Both a user specific leaderboard as well as an international leaderboard were implemented to foster competition as well as collaboration. Secondly, the application allows users to read landscape descriptions contributed by other users anywhere on earth through an intuitive map interface. Users can pan and zoom to a desired location and dynamic markers show the number and languages of available contributions at the respective location. Finally, a protected admin area allows authorised persons to moderate contributions as well as export the collected data.

The following sections present how the aesthetics, dynamics and mechanics of *Window Expeditions* were defined and implemented to fulfil the requirements set out in the previous chapter (cf. Chapter 3) guiding the development of the application.

4.2.1 Aesthetics

Since the main focus of *Window Expeditions* is motivating participants to crowdsource data, I first focused on the aesthetics before considering underlying dynamics and finally mechanics. The aesthetics of an application encompass the "desirable emotional responses evoked in the player, when she interacts with the game system" (Hunicke et al., 2004, p. 2) and thus primarily include visual as well as motivational aspects. The MDA framework lists core aesthetics, of which discovery, expression and



(a) Language Selection (b) Starting page

Figure 4.1: Screenshots of Windows Expeditions

fellowship were identified as most suited for *Window Expeditions*. These aesthetics show considerable overlap with the key gamification elements of exploration as well as collaboration and competition (cf. Chapter 3), highlighting the potential of adding gamified elements to motivate user participation.

Discovery: People are intrigued by playfully uncovering secrets or discovering new worlds, especially if their experiences can be communicated and shared with others. This fascination for exploration and sharing progress is reflected in highly successful location-based games such as Pokémon GO and Geocaching (Balzan and Debono, 2018; Laato et al., 2019a). In addition, many games and gamified platforms incorporate elements of discovery as a key motivational incentive for participation and engagement (Bleumers et al., 2012). Therefore, allowing for exploration and discovery was considered an important aesthetic in developing *Window Expeditions*.

Expression: Writing and sharing textual descriptions and exploring what other users have contributed can be seen as a form of self expression (Kovač, 2016) and as such a motivational incentive to take part. The aesthetic of expression revolves around allowing for expressive freedom in contributions by encouraging the use of natural language in favour of predefined categories. In addition, the MDA framework defines the aesthetic of expression as a form of self-discovery (Hunicke et al., 2004). This was interpreted loosely to also include the discovery of the immediate surroundings of the self, or in other words, the (re)discovery of contributors' everyday lived landscapes.

Fellowship: Finally, the aesthetic of fellowship is closely related to the key gamification elements of competition and collaboration. *Window Expeditions* aimed to allow the sharing and exploration of landscape descriptions which should induce a feeling of collaboration and belonging (cf. Baruch et al., 2016). This has been identified as a key motivational element in other crowdsourcing projects (Ryan and Deci, 2000; See et al., 2016). Since the application was developed and published during the global Covid-19 pandemic, the application was built to offer a way of visiting far away destinations, albeit digitally and through contributed textual descriptions. By allowing users to explore distant landscape descriptions written by other users, I hoped to further strengthen the feeling of fellowship.

4.2.2 Dynamics

Once the key aesthetics of *Window Expeditions* were identified, the needed dynamics to enable the intended experiences were addressed. An application's dynamics encompass all interactional features of an application expressed through "the run-time behavior of the mechanics acting on player inputs and each others' outputs over time" (Hunicke et al., 2004, p. 2). Seeing that *Window Expeditions* was implemented as an active spatial crowdsourcing platform to generate natural language descriptions, the main dynamics constitute the fundamental features of the application which can broadly be divided into four groups of dynamics:

1. General dynamics: General interactions with the application including navigation as well as displaying information
2. Contribution dynamics: Interactions concerning the contribution features of the application and how users can participate
3. Exploration dynamics: Interactions relating to how existing contributions can be explored
4. Moderation dynamics: The administrative tools allowing users and contributions to be moderated

This section first presents the general dynamics before going into more detail on contribution, exploration and moderation dynamics.

General Dynamics

When users first visit *Window Expeditions* they are asked to choose their preferred language (Figure 4.1a) which has been called for in multilingual user interfaces

(Miraz et al., 2016). Once a language is chosen, a user is directed to the main menu in the respective language (Figure 4.1b) where the user can choose to contribute, explore, login, read more about the project in the about section or read the newsletter. In addition, users have the possibility to sign up for the newsletter.

The entire user interface was implemented to dynamically adjust to the device screen resolution to allow participation from both mobile phones (Figures 4.1, 4.4 - 4.5 & 4.10) as well as devices with larger screens (Figures 4.2 - 4.3 & 4.6 - 4.9). This is known as responsive design which is a cornerstone in contemporary online application design (Patel et al., 2015).

The about section is a static information page about the application and includes the data privacy statement. Including free and prior informed consent as well as being transparent about data protection and privacy efforts is crucial in modern online application design (cf. Recital 42 - Voigt and Bussche, 2017) and is argued to increase the public's trust in science (Wiewiorówski, 2020), albeit effects on user participation seem minimal (Cummings et al., 2015).

The leader board page dynamically shows regions and users ranked by number of respective contributions (cf. Figures 4.3 & 4.2). The participant leader board is only displayed if users are logged in to enhance privacy and provide an incentive to sign up. The account page displays provided account information and a minimal number of options. In addition, the number of contributions and given likes are shown. The account page also allows participants to log out as well as deleting all user data including a user's contributions, in line with the general data protection regulations (Voigt and Bussche, 2017).

Contribution Dynamics

The contribution page interactively guides the participants through the contribution process and is central in collecting needed data. If a participant would like to contribute and is not logged in, a page showing free and prior informed consent is shown which the user must agree to before continuing. This ensures that every user is informed on how their data will be stored, analysed and shared which is an important aspect of data protection (Voigt and Bussche, 2017) and builds trust in the academic project (cf. Wiewiorówski, 2020).

Once consent is given the application tries to identify the device's location or allows users to input their own location by clicking on the map (Figure 4.4b). The current location of a user is shown on the basemap with a marker and the containing hexagon is shown (Figure 4.4b). If not satisfied with the location, a user can change

Figure 4.2: International leader board

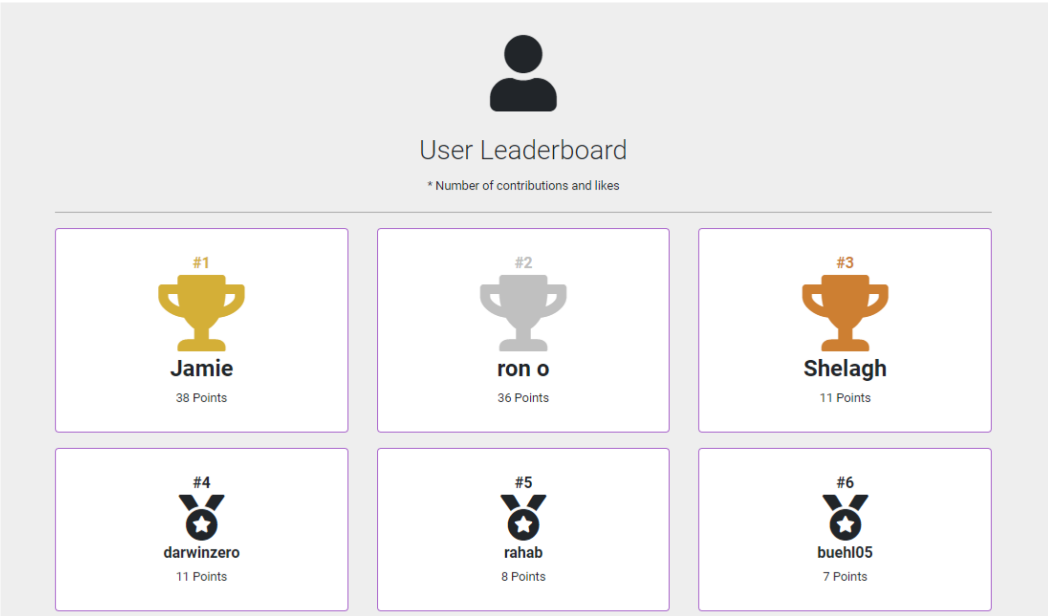
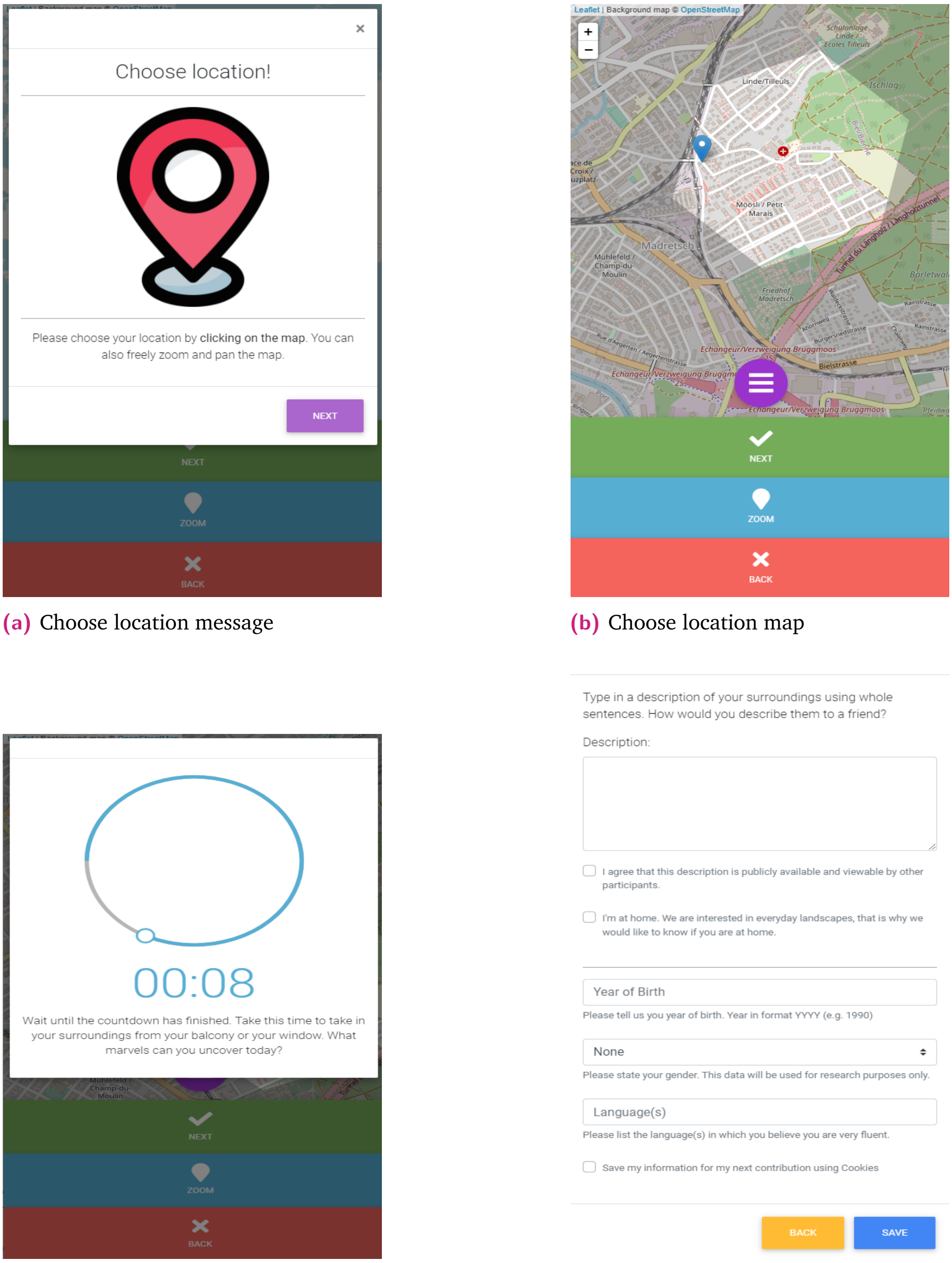


Figure 4.3: User leader board

the location of the marker by clicking the map in a new location or by dragging the marker to a desired location. Setting a new location also triggers the recalculation of the highlighted hexagonal area. If a user pans or zooms away from the marker, the "zoom" button in the bottom menu will zoom the map back to the position of the marker. Once a user is content with the indicated location, the user can click on "next" and is taken to a countdown timer (Figure 4.4c). If no location has been submitted, the prompt indicating a user should choose their location reappears (Figure 4.4a). The user's exact position is never transmitted to the server and only the ID of the containing hexagon is transmitted. This is to ensure data protection through spatial obfuscation (cf. Duckham and Kulik, 2005) in addition to data aggregation, which can potentially leak spatial information and user characteristics (cf. Fefferman et al., 2005; Pyrgelis et al., 2017).

The countdown serves to motivate users to take in their surroundings and think about their immediate environment instead of reciting from memory. Once the countdown timer has finished, the main contribution form is displayed where users are asked to add a natural language landscape description of their immediate surroundings (Figure 4.4d). Special attention was paid to the formulation of the task to not prime users towards specific senses. After careful consideration, including consulting colleagues in linguistics, the following formulation was deemed most suitable: "Type in a description of your surroundings using whole sentences. How would you describe them to a friend?". However, it should be noted that the effects of different task formulations on contribution behaviour were not tested.

Next, users are asked to report on basic demographic information such as year of birth, gender and the languages a user believes to be fluent in. If a user is logged in or decides to store demographic information in a cookie the demographic data is automatically attached. Since the application aims to collect descriptions of everyday lived landscapes, users are also asked if they are currently at home or not. Finally, a user is asked for consent to publicly display their contribution on the world map.



(a) Choose location message

(b) Choose location map

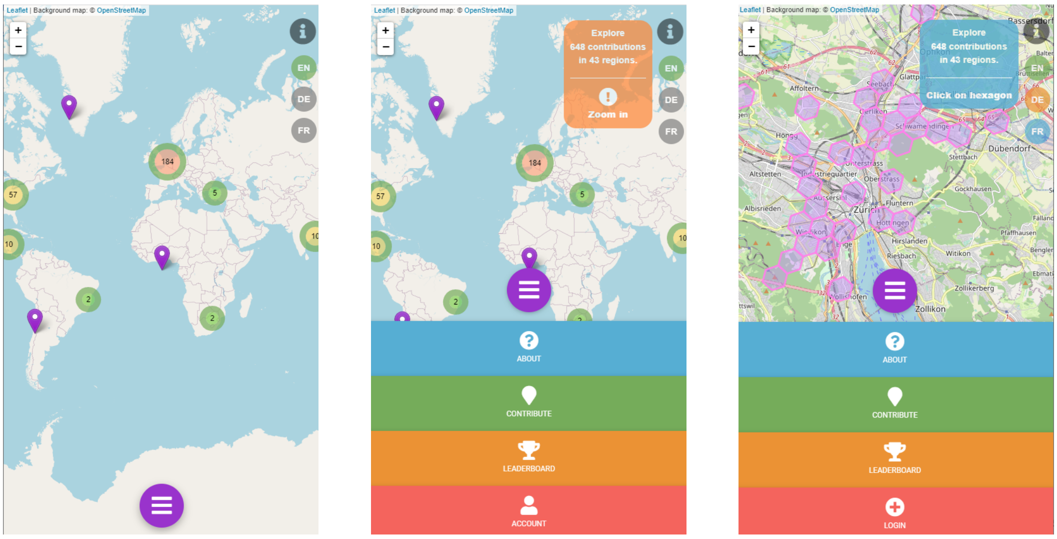
(c) Countdown timer

(d) Contribution form

Figure 4.4: Screenshots of Window Expeditions' contribution feature.

Exploration Dynamics

If a user clicks on explore, the exploration screen opens. The exploration screen includes buttons to adjust the zoom level of the map display (Figure 4.9) and an info box displaying the number of contributions and regions as well as prompting the user to either zoom in or click on a hexagon. A collapsible menu is found at the bottom centre of the screen, a position which has been identified as easily accessible for mobile users (Bergstrom-Lehtovirta and Oulasvirta, 2014; Charland and LeRoux, 2011). All menu buttons were implemented to load content on a new page. The collapsible menu is dynamic and slightly changes if the user is logged in (Figure 4.5). The exploration screen also includes language filter buttons which dynamically load and unload contributions according to the chosen languages (Figure 4.6 & 4.7). This is in line with Shneiderman's *Visual Information Seeking Mantra* summarising the most important visual design principles as giving an overview which can be manipulated by zoom and filter functionalities and only showing details on demand (Shneiderman, 1996; Craft and Cairns, 2005). A basemap situates contributions in their respective spatial context. Basemaps provide the user with location-based information on a gradient of abstraction from satellite images to minimalistic vector maps (cf. Li et al., 2020). For *Window Expeditions*, a minimalistic basemap was chosen to minimise user priming towards specific features shown on the map. The application uses LeafletJS[1] to retrieve and display OpenStreetMap[2] (OSM) data (Haklay and Weber, 2008) on an interactive web map. Users can explore areas of interest and spatially filter contributions by panning and zooming to a desired extent on the world map (Figure 4.9).



(a) Mobile exploration screen

(b) Mobile exploration screen zoomed out

(c) Mobile exploration screen zoomed in

Figure 4.5: Screenshots of Windows Expeditions mobile exploration view

[1] www.leafletjs.com (accessed: 17.05.2022)
[2] www.openstreetmap.org (accessed: 17.05.2022)

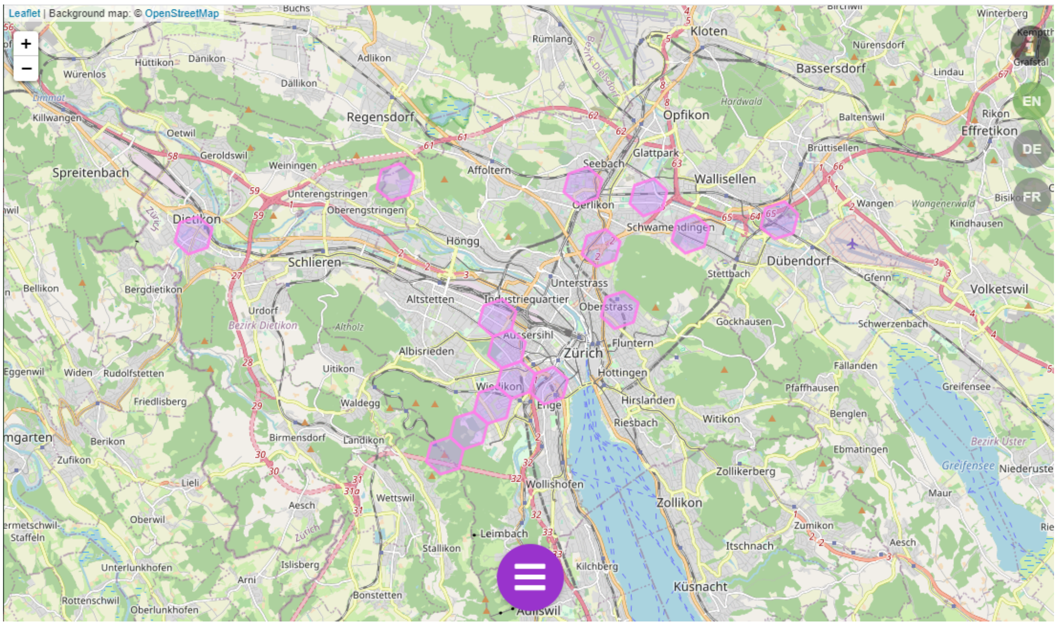


Figure 4.6: Exploration view of the area of Zurich, Switzerland and the hexagonal areas corresponding to German contributions

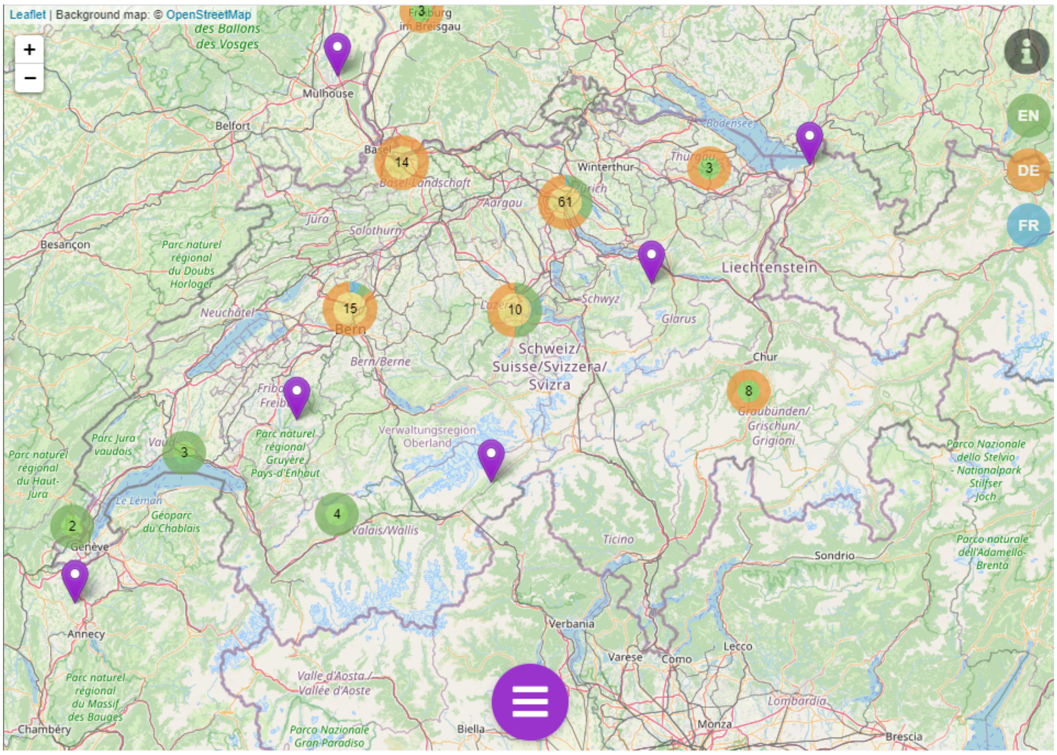


Figure 4.7: Exploration view of Switzerland showing all contributions

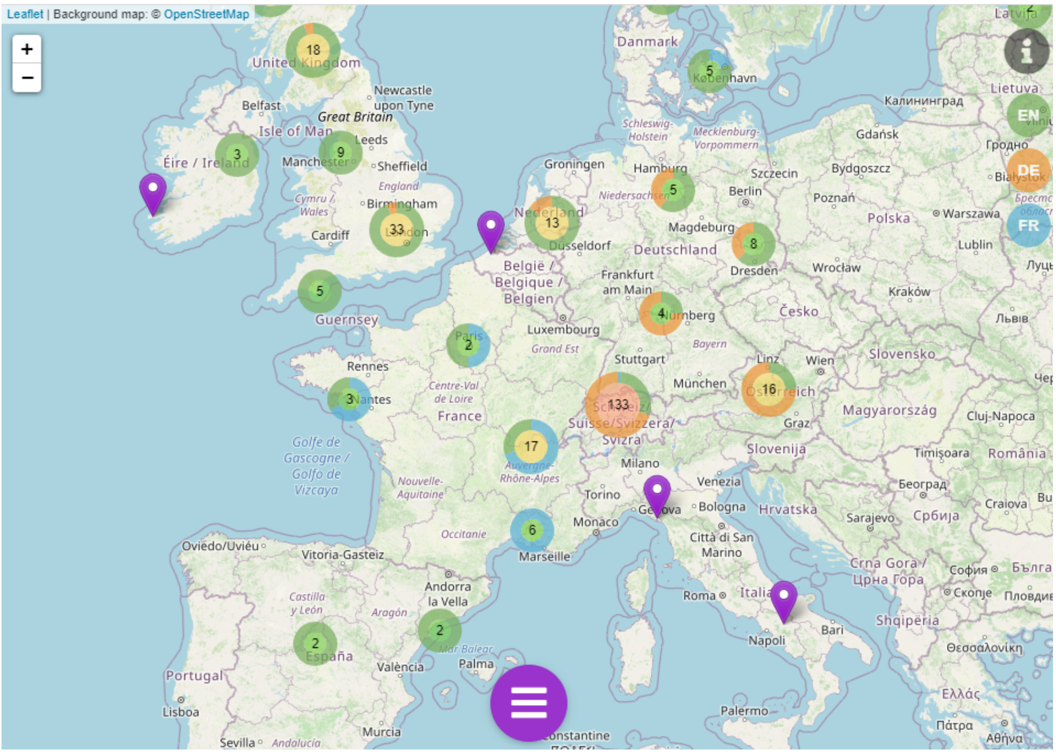


Figure 4.8: Exploration view of Europe

Figure 4.9: Exploration view of the world

Contributions are depicted as interactive markers and if overlap is detected on a given zoom level, markers are clustered (Figure 4.8). The application combines markers to clusters showing the number and percentage of contributions in a given cluster stratified by language. If a cluster is clicked on, the application automatically calculates the necessary zoom level needed for the cluster to split into smaller clusters or individual markers and zooms in. If a marker is clicked, the application automatically zooms in to display the contribution extent by dynamically replacing individual markers with the hexagons representing the extent of contributions. The hexagons are approximately 1km in diameter and are calculated using the hexagonal spatial clustering algorithm H3[3].

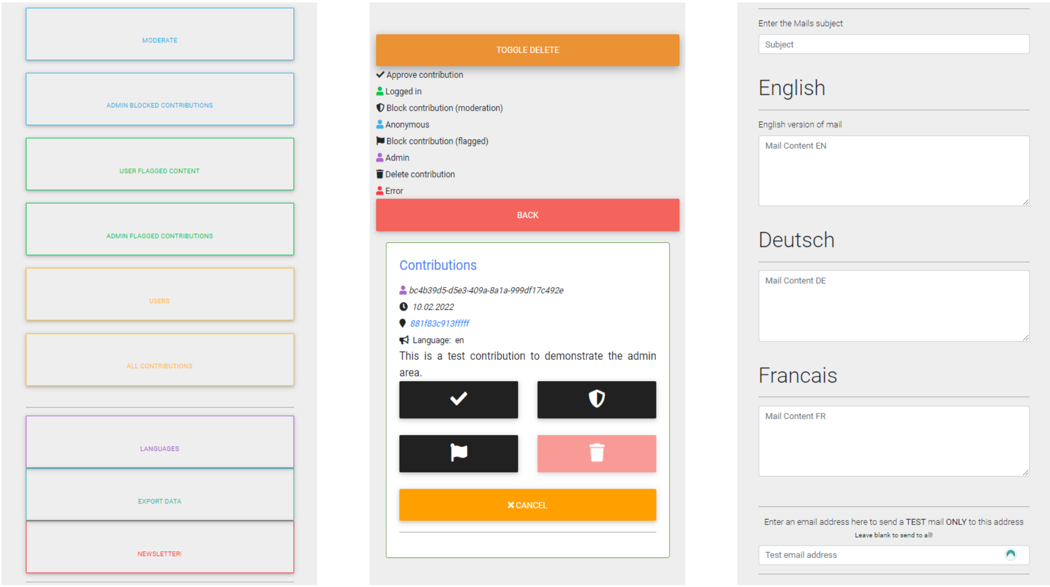
Moderation Dynamics

Since *Window Expeditions* collects and publicly displays user contributions, administration and moderation tools become necessary. A restricted admin area was implemented to add moderation capabilities as well as exporting data for scientific analyses and facilitating outreach (Figure 4.10a).

A moderation tool was developed to allow contributions to be accepted or rejected. Moderating user generated content has been found to ensure contribution quality (Chen et al., 2011), especially when the amount of contributions increases (Ghosh et al., 2011). All new contributions are initially only visible to the moderators in the moderation tool and can either be accepted, blocked, flagged or deleted. In addition, the moderation tool shows the contributors role (logged in, anonymous or admin), a unique user identifier (if further inquiry is needed), the time of the contribution and the language of the application when the contribution was uploaded (Figure 4.10b). In addition, a clickable location identifier of the contribution is shown which takes the moderator to the contribution location on a map. This is especially important to identify and rule out spoof coordinates or highly implausible locations. Obviously faulty contributions can be deleted through the tool. To avoid unintentional deletion of contributions, the delete button must first be activated at the top of the page. Blocked contributions are kept in the database but not displayed publicly, flagged contributions are blocked and stored in a separate category to allow further inspection by other moderators and deleted contributions are completely removed from the database.

To manage existing contributions, a feature was implemented showing all contributions as well as chosen metadata and allowing each contribution to be moderated. The added bulk editing functionality also allows for multiple contributions to be moderated simultaneously. The administration tool of *Window Expeditions* includes

[3] https://eng.uber.com/h3/ (accessed: 13.06.2022)



(a) Admin menu **(b)** Inspecting contributions **(c)** Newsletter tool

Figure 4.10: Screenshots of Windows Expeditions admin area

a user administration page which lists all users and allows users to be assigned different roles (user, moderator, administrator). Users can also be deleted upon which all user data and user contributions are deleted irreversibly in line with the *right to be forgotten* in contemporary data protection laws (Voigt and Bussche, 2017).

Further, features were implemented to export needed data for scientific analyses and for public outreach using a newsletter (Figure 4.10c). The export tool provides a possibility to run predefined queries and save the result as a spreadsheet. The queries are hardcoded in the application and the tool does not allow for exporting custom queries. This was implemented to add an additional layer of protection and to ensure the exported data is in line with the data protection statement found in the about section of the application. If data is exported, *Window Expeditions* queries the specified tables, returns the needed data and decrypts encrypted fields. To further enhance data protection, exported data is not made directly available for download. Instead, the data is transferred and stored in a secure location which is only accessible for authorised persons.

Finally, a newsletter feature was implemented to allow for public outreach. Outreach has been found to increase contributions in public participation projects (Sauermanna and Franzonib, 2015) with newsletters belonging to the most favoured outreach strategies (Schulwitz et al., 2021). The newsletter tool allows an administrator to define a subject line and a message in the languages of the application (at the time of writing: English, German and French). The tool also allows the administrator to input an email address to send a test version of the newsletter. When the administrator is content with the newsletter email, the tool offers the possibility to send the newsletter to all users who actively opted into receiving newsletter mails.

4.2.3 Mechanics

The presented aesthetics that emerge from the dynamics are built on and enabled by the underlying mechanics. The mechanics of an application encompass the "particular components of the game, at the level of data representation and algorithms" (Hunicke et al., 2004, p. 2) and build the backbone of any application.

Window Expeditions was implemented using NodeJS[4] as the underlying backend system. The application was primarily programmed in JavaScript and is hosted on the Google Cloud infrastructure in Zurich, Switzerland. The project was implemented using GIT[5] as the version control system and development was split into a development branch on which features were implemented in an iterative approach, and a release branch which was accessible by the general public. Version or source control is an important part of iterative software development and separating development and release environments is common practice (Williams et al., 2011; Jones et al., 2021).

The implementation itself was separated into the application routing, controllers, views and an underlying MySQL[6] database (cf. Figure 4.11). This approach shows many parallels with the model, view, controller (MVC) framework (Krasner and Pope, 1988) which remains common in online application development (Pop and Altar, 2014). The routing relays incoming requests to the needed application logic and dynamically adapts requests depending on the user's logged-in state. For example, if a user clicks on contribute the application relays the input of the button press to the contribution controller which contains all application logic needed to run the contribution feature. The application logic is stored in controllers which contain all code needed to interpret the provided input and return the desired output, including checking the integrity of a user's contribution and if all fields fulfil all requirements before saving the contribution to the database and returning a success message. The views of *Window Expeditions* encompass all visual templates as well as client-side JavaScript code that is sent to the user. The views are coded using embedded JavaScript templating (EJS) and are adaptive to a user's role as well as logged-in status. For instance, once a contribution has been successfully stored in the database, the success view is sent to the user which renders a success screen on the user's device.

[4]www.nodejs.org (accessed: 17.05.2022)
[5]www.git-scm.com (accessed: 17.05.2022)
[6]www.mysql.com (accessed: 17.05.2022)

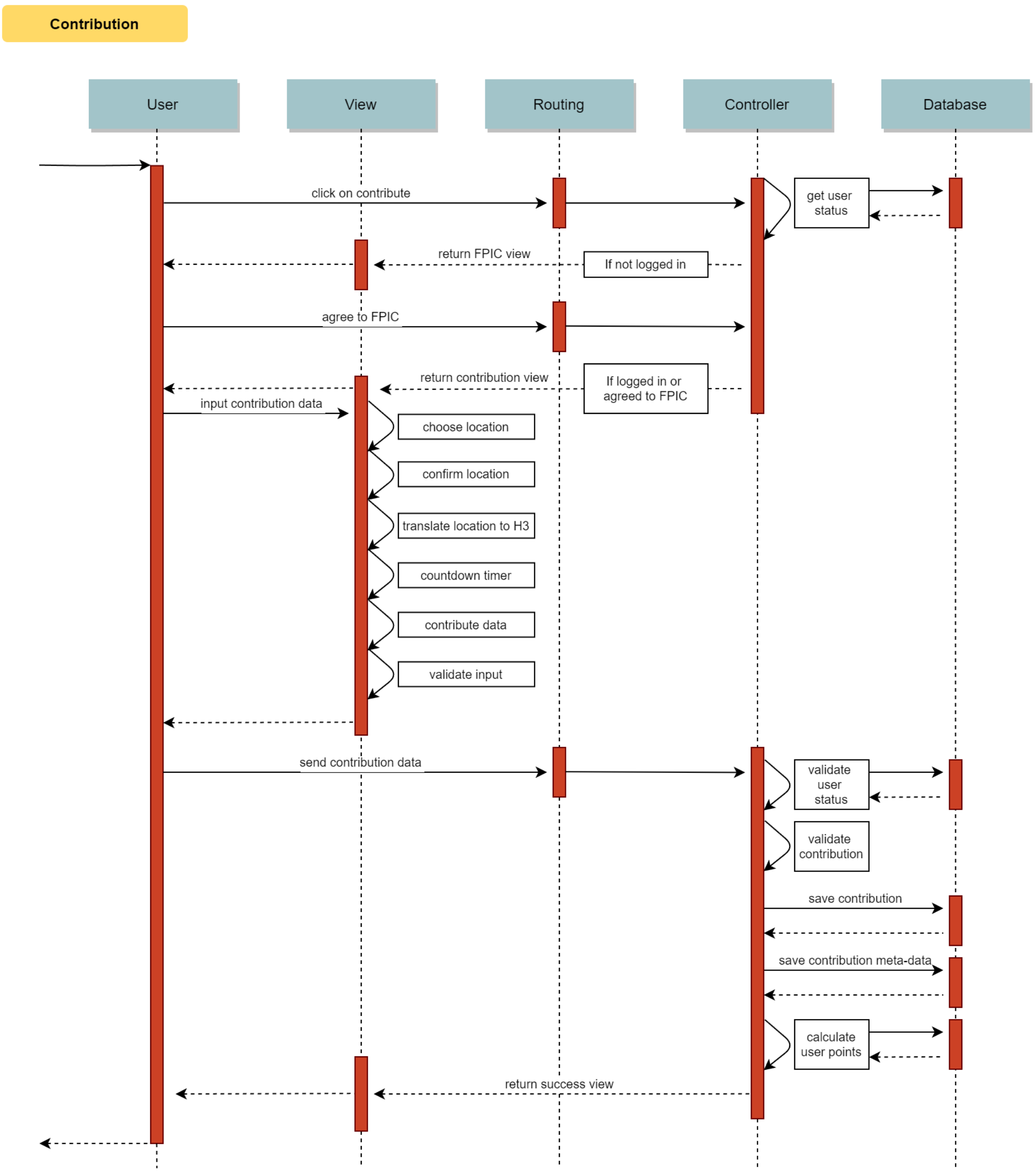


Figure 4.11: UML of the contribution pipeline

The final major component of the application is the database where all data is stored. In *Window Expeditions* MySQL was chosen as the underlying relational database and multiple tables were defined to store application-relevant data. MySQL is a widely used relational database which stores information in predefined tables and cells. For the implemented application this includes tables containing information about the registered users, participant information, contributions and location information from GeoNames[7]. Sensitive information was encrypted with bcrypt (cf. Ntantogian et al., 2019), before being saved on the server. The database structure and relations are summarised in (Figure 4.12).

[7]www.geonames.org (accessed: 17.05.2022)

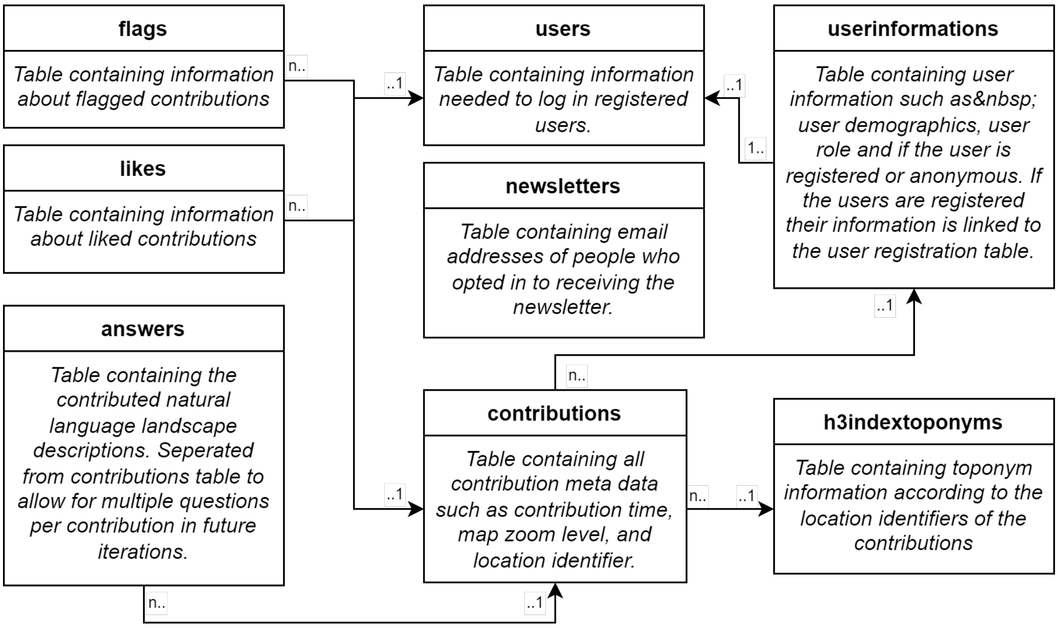


Figure 4.12: UML of data tables

4.3 Testing and promotion

After implementing the mechanics that enable the dynamics resulting in the aesthetics of *Window Expeditions*, the application was tested with a group of select individuals. In an attempt to include a diverse group of testers representing the target audience of the application, I recruited 19 individuals with a balance between male (n = 8) and female (n = 11), covering a wide range of age groups (11 yrs - 78 yrs) and speaking German (n = 10) and English (n = 9). The testers were asked to use the application and report on any issues they encountered. Users were also encouraged to make suggestions on how *Window Expeditions* could be improved. The feedback was collected through discussions as well as email and the application was improved accordingly.

The first version of the application included a quiz feature where interested users were given a random landscape description and had to guess the location of the description. This quiz feature was removed after many testers reported it being too difficult due to the uploaded descriptions seldomly having enough information to pinpoint the location. The quiz functionality was replaced with the presented exploration view where users can explore all moderated public contributions on a world map. Further, various users reported issues with the contribution feature. Most notable issues included being able to upload a contribution without confirming the location and emoticons leading to server errors due to server-side text sanitising. These issues were resolved by reiterating the contribution functionalities and streamlining the contribution process.

After improving various features of the application according to the test feedback, *Window Expeditions* was opened to the general public on 14.09.2020. The application was primarily promoted through emails, on social-media platforms and in lectures and presentations. Data on the effectiveness of individual channels of promotion was not collected. However, the promoters of the application noticed individually addressed emails to have the highest turnaround. The promotional efforts were conducted multilingually in English, German and later French. A small number of participants sent unsolicited feedback mentioning bugs or suggestions for improvements. A commonly requested feature was the opportunity to participate as an anonymous user without having to register, which was added to the application on 29.10.2020. In addition, since the application aims to create a multilingual corpus, the application was also translated to French and opened to the public on 03.12.2020.

Analysing the Generated Data

5

> *I have forgotten much that I thought I knew, and learned again much that I had forgotten.*
>
> — **John Ronald Reuel Tolkien**
>
> (Author)

After developing and implementing *Window Expeditions* the corpus of generated natural language landscape descriptions was exported and analysed. Various quantitative and qualitative methods from geographic information science to computational linguistics were combined into specific workflows to explore and interpret the data. This chapter presents the methods and approaches used to analyse the corpus of in-situ natural language landscape descriptions. First, methods of characterising the crowd in terms of the demographics and languages of the participants are discussed. This chapter then presents how the locations of contributions were analysed before discussing how the contents of the contributions were explored and interpreted. Finally, this chapter concludes by introducing methods of using the generated corpus to identify similar documents in other corpora.

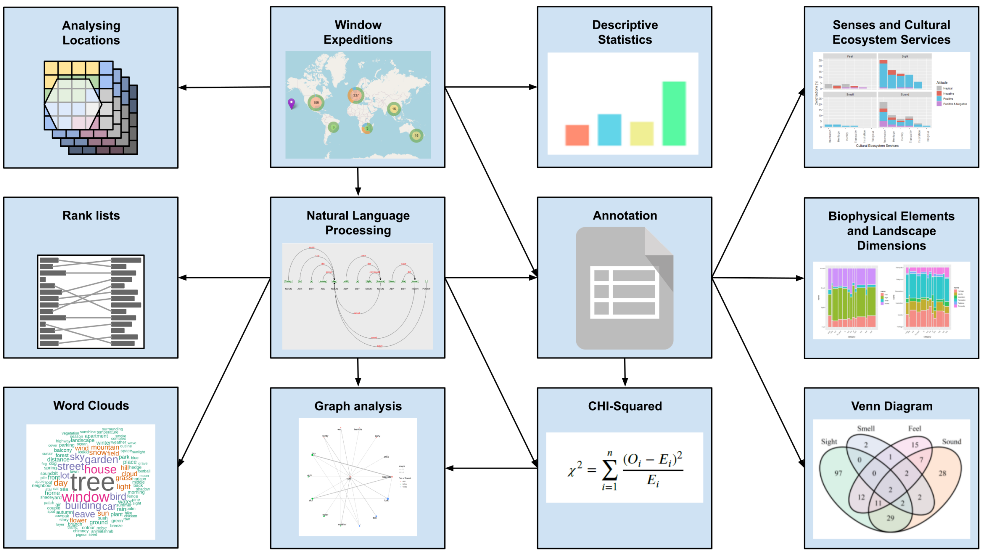


Figure 5.1: An overview of the used methods and their relations

5.1 Characterising the crowd

5.1.1 Basic demographics

To get an overview of the corpus the data was exported and characteristics of the users were explored. Firstly, the number of contributions per user role (e.g. registered and anonymous) as well as the number of individual contributions per user were calculated. To investigate the age distribution of participants the minimum, maximum, median and mean reported age was calculated and the percentage of participants between the common working ages of 18 and 65 was elicited. Further, the reported genders were summarised and plotted.

5.1.2 Languages

To explore the languages of participating users the user reported free text list of languages was first processed and individual languages were identified and grouped. Giving the users the possibility to add free text allows for expressive freedom in how and what is reported (cf. Chapter 4.2). However, free-text lists call for complex matching queries to extract various formats of reporting (e.g. users reporting: "English and German" as opposed to "Deutsch; English" or "EN DE"). In a first step, a regular expression was used to split user reported strings, potentially containing a list of languages, into individual elements.

In a further step, the array of extracted potential languages is compared to predefined lists of language referents (e.g. for English this lists includes: "english", "englisch", "englis", "en", "e", "anglais", "en_us", "ingles") and annotated as being either English, German, French or other. All extracted terms that are not found in any predefined list and thus annotated as other are saved as a separate list. By manually inspecting the list, false-negatives (language referents that refer to English, French or German but are not in the respective list of referents) were identified and added to the respective predefined list of language referents. The language elicitation approach resulted in each contribution being complemented by additional information about the language in which *Window Expeditions* was used and the languages the users believed to be fluent in. These were plotted and differences between the language of the application and the distributions of reported languages of the participants were explored.

In a final step, the contributions were analysed in terms of contribution length as a function of application language. The contributions were split into individual words and these were counted. The differences between the number of words per contribution between languages was explored using a Wilcoxon rank sum test with continuity correction to compare the distributions and test for significant differences.

5.2 Characterising the locations of contributions

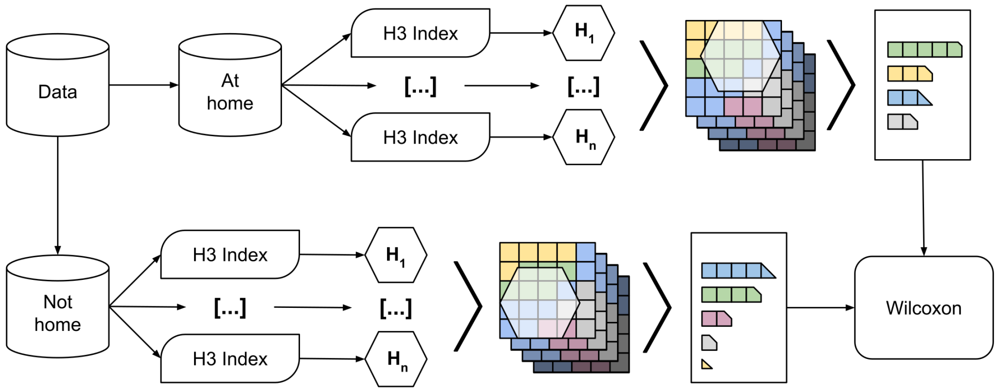


Figure 5.2: Schematic representation of analysing locations

Each contribution was assigned a unique location identifier corresponding to a hexagonal area of approximately 1km in diameter (cf. Chapter 4). Erroneous locations such as null island - coordinates having longitude and latitude of 0 due to server, client or user errors which can commonly be found in user generated geographic information (Janowicz et al., 2016) - were removed for spatial analyses. However, the descriptions were kept for further natural language processing where spatial locations were not relevant. In addition, a small number of contributions seemed implausible since they were in the sea or on small uninhabited islands. However, on further inspection of the written descriptions it became clear that these locations were referring to what was being described in the contribution rather than the location of the contributor, which is a common artefact also found in georeferenced images (cf. Zielstra and Hochmair, 2013). In the vast majority of the contributions the user specified locations were deemed accurate and used for further analyses.

The aim of *Window Expeditions* was to generate a corpus of natural language descriptions of everyday lived landscapes. Generally, these encompass the residential areas near home, especially during the global pandemic and the resulting reduced mobility (cf. Venter et al., 2020; Ugolini et al., 2020; Borkowski et al., 2021; Baumeister et al., 2022). To analyse where participants contributed from, the locations of contributions to *Window Expeditions* were compared with the land cover types of Copernicus (Buchhorn et al., 2020) (cf. Figure 5.2). The unique location identifier was used to calculate the corner coordinates spanning the hexagonal polygon representing the contribution area. In addition, the surface area was calculated. Hexagonal polygons were overlain with the Copernicus land cover raster and the raster cells overlapping in some form with the hexagonal areas were extracted and their percentage of respective overlap was calculated. Multiple land cover values were found in most hexagonal areas. These were summarised resulting in the relative land cover distribution within each hexagonal area which can be translated to the total area of individual land cover classes within a contribution area. All areas were summarised and the relative proportions of land cover types in all contribution areas was plotted.

To further investigate the differences in contribution locations between participants reporting being at home and those not reporting being at home, the contributions were split into these two respective groups and the relative land cover types were calculated. To test for significant differences between the land cover types found in contribution areas of people reporting being at home as opposed to not being at home a non-parametric Wilcoxon signed rank exact test was performed and the individual results were plotted.

5.3 Characterising the contents

Gleaning insights into underlying structures of languages and comparing collections of natural language is the subject interest of corpus linguistics, albeit the definition and understanding of what corpus linguistics encompasses varies (Taylor, 2008). Computational analyses of natural language commonly aim at characterising a corpus in terms of linguistic properties (Taylor, 2008; Gries, 2009; Gries and Berez, 2017), comparing different corpora to identify similarities and differences (Kilgarriff, 2001) and investigating if a corpus is specific for a certain domain (Sekine, 1997; Kilgarriff, 2001). Commonly, specific frequencies such as the number of distinct terms, co-occurrences and part of speech types are elicited before applying some form of statistical testing (Gries, 2009). When going beyond frequency based analyses such as exploring underlying semantics, computational methods are generally complemented with human annotation or qualitative coding approaches (cf. Blaylock et al., 2009; Derungs and Purves, 2014; Elliott, 2018), with increasing interest in crowdsourcing and gamified systems (Poesio et al., 2017).

In the following section, methods and workflows of analysing the contents of descriptions uploaded to *Window Expeditions* are presented. This section first introduces the applied natural language processing pipeline before introducing various workflows for investigating salient terms in different corpora, comparing the corpora of different languages and exploring different terms' context through graph analyses.

Finally, this section presents how contributions were annotated to add information on sensory experiences and cultural ecosystem services.

5.3.1 Natural language processing

After exploring who the contributors were and where they contributed from, I analysed the contributions in regards to the contents of the descriptions. In order to explore the contents of the contributions in detail, various workflows were created and implemented for many of which natural language processing served as the starting point. The descriptions contributed to the English, German and French versions of Window Expeditions were parsed with SpaCy[1] using the models *en_core_web_lg*, *de_core_news_lg* and *fr_core_news_lg* for English, German and French parsing respectively. The algorithm takes a collection of texts as input and divides individual contributions into single sentences which are then further split into tokens such as individual terms and punctuation. Using the mentioned models, SpaCy elicits various linguistic properties and returns a table (cf. Figure 5.3) containing the following information:

Doc_id: The unique identifier of a given contribution

Sentence_id: A unique identifier for each sentence within a contribution

Token_id: A unique identifier for each token within a sentence

Token: The original token including terms and punctuation

Lemma: The lowercase root of a token

Pos: The part of speech type of a token

Head_token_id: A reference to another token within the same document and sentence

Dep_rel: The syntactic relationship between a given token and the token referenced through the head_token_id

Entity: The identified named entity of a token such as "work of art", "quantity" or "person"

[1] www.spacy.io (accessed: 20.05.2022)

doc_id	sentence_id	token_id	token	lemma	pos	head_token_id	dep_rel	entity
228	1	1	A	a	DET	4	det	
228	1	2	small	small	ADJ	4	amod	
228	1	3	suburban	suburban	ADJ	4	amod	
228	1	4	garden	garden	NOUN	4	ROOT	
228	1	5	in	in	ADP	4	prep	
228	1	6	South	South	PROPN	7	compound	LOC_B
228	1	7	London	London	PROPN	5	pobj	LOC_I
228	1	8	in	in	ADP	4	prep	
228	1	9	late	late	ADJ	10	amod	DATE_B
228	1	10	autumn	autumn	NOUN	8	pobj	DATE_I
228	1	11	.	.	PUNCT	4	punct	

Figure 5.3: An example of the output of SpaCy for the sentence: "*A small suburban garden in South London in late autumn.*"

5.3.2 Comparing salient terms in different languages

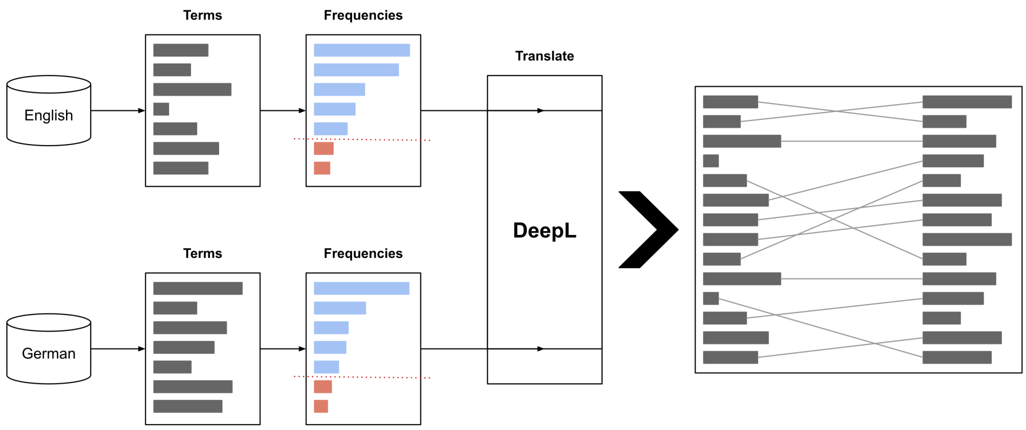


Figure 5.4: Schematic representation of comparing languages

Having a collection of parsed landscape descriptions annotated with linguistic information from the natural language processing step opens the door to a variety of explorations of the data. To investigate and compare salient terms in different languages, distinct combinations of lemmas and part of speech types were counted. The 50 most frequent noun, adjective and verb lemmas were extracted from each language with sufficient data. Each individual lemma was translated into the respective other language using DeepL[2], a machine translation service, after which stop words were removed using predefined stopword lists. DeepL produces highly accurate results if given a whole text, however, the accuracy decreases when translating individual terms, which is a common issue in computational translations (Reber, 2019).

[2] www.deepl.com (accessed: 17.05.2022)

The part of speech type is not taken into account and thus introduces ambiguity where the part of speech type of the translation does not necessarily match the original term's part of speech type. Further, if multiple viable translations are found DeepL only returns the most probable term according to its underlying linguistic modelling, at times leading to obscure translations (e.g. "home" is translated to German as "startseite" which is translated back to English as "home page"). Nevertheless, the presented fully computational approach makes the results scalable whilst remaining reproducible as long as the DeepL translations remain stable. Finally, the 50 most frequent terms were plotted for each pair of languages according to their rank and linked where the translated term was found in the other language (Figure 5.4).

5.3.3 Exploring natural language through word clouds

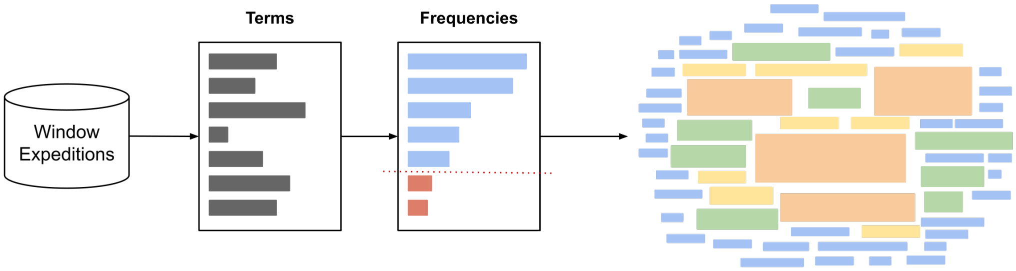


Figure 5.5: Schematic representation of generating wordclouds. Both size and colour represent frequency to exemplify that both size and colour can be used as visual variables.

A common approach to visualising textual information such as term frequencies or some form of term saliency measure is through word clouds (cf. Cui et al., 2010; DePaolo and Wilkinson, 2014; Rayson et al., 2017; Hearst et al., 2020). Word cloud algorithms use space optimisation approaches of arranging terms within a predefined shape or around a focal point (cf. Feinberg, 2010). Terms within a word cloud are generally styled according to some properties such as scaling terms' size to reflect frequency or colouring terms according to predefined categories (cf. Cui et al., 2010; DePaolo and Wilkinson, 2014). Word clouds are commonly used for a first qualitative inspection of the most frequent terms of a corpus. However, the legibility of word clouds and their applicability for visualising scientific data is debated (DePaolo and Wilkinson, 2014; Hearst et al., 2020).

Nonetheless, seeing their ability to provide a quick and effective overview over textual data, word clouds were used in this thesis as a visualisation tool to present salient terms and their frequencies (Figure 5.5). To generate word clouds the landscape descriptions contributed to *Window Expeditions* were parsed and individual term lemmas were grouped according to their part of speech. The frequency of distinct term lemmas was elicited within each group and word clouds were drawn for each group with all terms that occurred twice or more. A term's size corresponded to its frequency within the visualised data, allowing for quick identification and inspection of the most frequent terms within a word cloud.

5.3.4 X^2 testing

Comparing two corpora is a widely adopted approach to elicit differences and similarities in the ways in which language is used (Kilgarriff, 2001; Gries, 2009). Exploring differences and similarities of different collections of natural language can shed light on the domain specificity of a given collection and can help identify over or underrepresented terms. Terms that are significantly over or underrepresented in one corpus compared to another can tell us something about salient terminology, opening the door to further inquiry into the context of a term and underlying semantics. One common approach is calculating the χ^2 statistics (Kilgarriff, 2001). X^2 is commonly used to compare the distribution of a given variable in one dataset with another dataset and checks for significant differences. Here, χ^2 was used to compare the frequencies of terms in one collection with their respective frequency in another.

	t	*not t*	**total**
A	*w*	*x*	*w+x*
B	*y*	*z*	*y+z*
total	*w+y*	*x+z*	*w+x+y+z*

Figure 5.6: χ^2 contingency table

A 2x2 contingency table was created (Figure 5.6) with the observed frequencies (w and y) of a specific term (t) in two corpora (A and B) as well as the total number (x and z) of other terms (not t) in each collection. The resulting table contains the observed frequencies of terms that emerge from the two corpora. In addition to extracting observed frequencies, χ^2 calculates the expected frequencies of all cells of the contingency table. The expected frequencies are calculated using following formula:

$$E_i = \frac{row.sum * col.sum}{grand.total}$$

Where E_i represents the expected count of a given cell in the contingency table, $row.sum$ represents the sum of a given row in the contingency table (e.g. $w + x$), $col.sum$ represents the sum of a given column in the contingency table (e.g. $w + y$) and $grand.total$ represents the sum of all values in the contingency table (e.g. $w + x + y + z$). The expected counts are calculated for all cells in the contingency table (e.g. the expected frequency of a given term in corpus A would be calculated as: $E_w = \frac{(w+x)*(w+y)}{w+x+y+z}$). Finally, the χ^2 statistics were calculated using following formula, in line with standard corpus linguistics workflows (Kilgarriff, 2001; Chen and Chen, 2011):

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where E_i represents the expected frequency of a given cell of the contingency table and O_i represents the observed frequency. The resulting χ^2 value indicates if there is a significant difference in the frequency of a term (t) between two corpora (A and B) and can thus be used to identify significantly over and underrepresented terms in one collection compared to another.

5.3.5 Comparing the content to other corpora

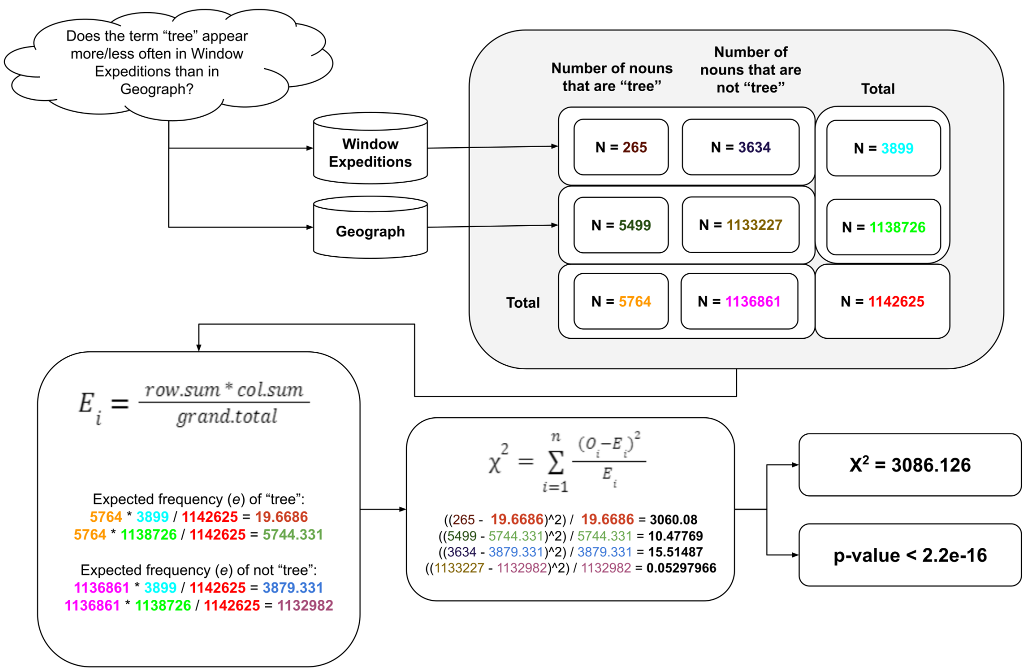


Figure 5.7: Schematic representation of using χ^2 to compare corpora

Window Expeditions aims at building a corpus of natural language landscape descriptions in multiple languages for the specific domain of landscape perception research. When building such a corpus it is important to gauge if the corpus is indeed domain specific and how it differs from the general use of language. Since *Window Expeditions* is interested in everyday lived landscapes, it makes sense to also compare the corpus to existing user generated sources of natural language in general as well as landscape descriptions. Thus, the corpus generated with *Window Expeditions*[3] was compared to a general corpus of the English language - the British National Corpus[4] (Kilgarriff, 1995) - as well as an actively crowdsourced collection of English landscape image descriptions from the *Geograph*[5] project aiming to collect representative images and descriptions of 1km^2 grid cells in the UK (cf. Chesnokova and Purves, 2018). A subset of English contributions to *Window Expeditions*[6] was compared to different English text collections. Other languages were not analysed due to the availability and access of comparable reference corpora. To compare $\mathbb{WE}^{en}$ to the mentioned $\mathbb{BNC}$ and $\mathbb{GEO}$ corpora, χ^2 statistics were calculated for all nouns, verbs and adjectives to identify terms that were significantly ($p < 0.01$) more frequent in $\mathbb{WE}^{en}$ than in the $\mathbb{BNC}$ and $\mathbb{GEO}$ corpora (Figure 5.7).

5.3.6 Exploring salient terms in sensory experiences and cultural ecosystem services

To further investigate sensory experiences and cultural ecosystem services through the lens of salient terms within each dimension, a subset of contributions was created for each dimension. For each contribution the nouns, verbs and adjectives, identified through the natural language processing workflow were extracted. The frequencies of terms within each dimension and part of speech type were compared to the respective frequencies within the whole corpus. For all terms the χ^2 statistics were calculated to identify terms occurring significantly ($p < 0.01$) more in one dimension (e.g. sight, sound, heritage, recreation etc.) compared to the whole corpus.

[3] In the following the notation $\mathbb{WE}$ is used to refer to this corpus
[4] In the following the notation $\mathbb{BNC}$ is used to refer to this corpus
[5] In the following the notation $\mathbb{GEO}$ is used to refer to this corpus
[6] In the following the notation $\mathbb{WE}^{en}$ is used to refer to this corpus

5.3.7 Graphs in corpus linguistics

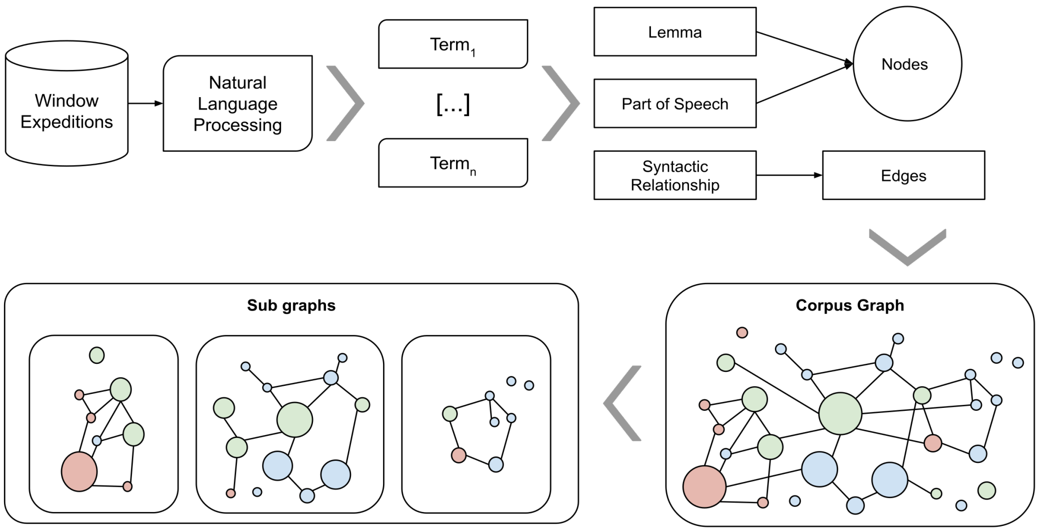


Figure 5.8: Schematic representation of generating graphs from a corpus parsed with SpaCy

Once a corpus has been parsed and linguistic properties of the individual terms have been annotated through natural language processing, a more in-depth exploration of the context of particularly salient terms becomes of interest. Graphs, or networks, show potential in visualising a selected term's context within a corpus as well as allowing for further analyses using graph and network based methodologies (cf. Desagulier, 2017; Rayson et al., 2017). Graphs have been used in computational linguistics to, for example, represent collocational data and to complement concordance analyses (cf. Rauscher et al., 2013; Luz and Sheehan, 2014; Rayson et al., 2017; Brezina, 2018). Graphs consist of directed or undirected nodes joined by edges (Desagulier, 2017). These can have attributes, for example, signifying the importance of a node or the strength of an edge joining two nodes. Graphs and networks are highly suited structures to explore data by starting at nodes of interest and traversing the network through edges. This allows for the exploration of the surroundings of a particular node, in other words, the node's context. For the analyses here, graphs were built to explore the context and connectedness of specific terms within the $\mathbb{WE}^{en}$ corpus collected with *Window Expeditions*. A graph representing the entire $\mathbb{WE}^{en}$ corpus was created using the information gleaned from the natural language processing workflow such as a term's part of speech type and it's syntactic relationships with other terms (Figure 5.8). Individual term lemmas represent the nodes and the computationally annotated syntactic relationships represent the edges of the created graph. In addition, the respective number of lemmas within the corpus and the number of edges between lemmas was calculated and added as metadata to nodes and edges respectively. To further investigate the context of particular terms, sub-graphs were extracted, where only particular parts of speech as well as only nodes joined by a minimum number of edges were included.

5.4 Annotating contributions

Despite advances in computational approaches of exploring and understanding natural language, more complex tasks such as understanding underlying meanings and sentiments remains challenging (cf. Chapter 2). Thus, human involvement through interpreting natural language and adding additional machine-readable data to a corpus - commonly referred to as qualitative coding or annotation - remains crucial. Annotating the $\mathbb{WE}^{en}$ corpus was divided into individual workflows for biophysical elements, sensory experiences and cultural ecosystem services. In the following, this section introduces each annotation task used.

5.4.1 Biophysical elements

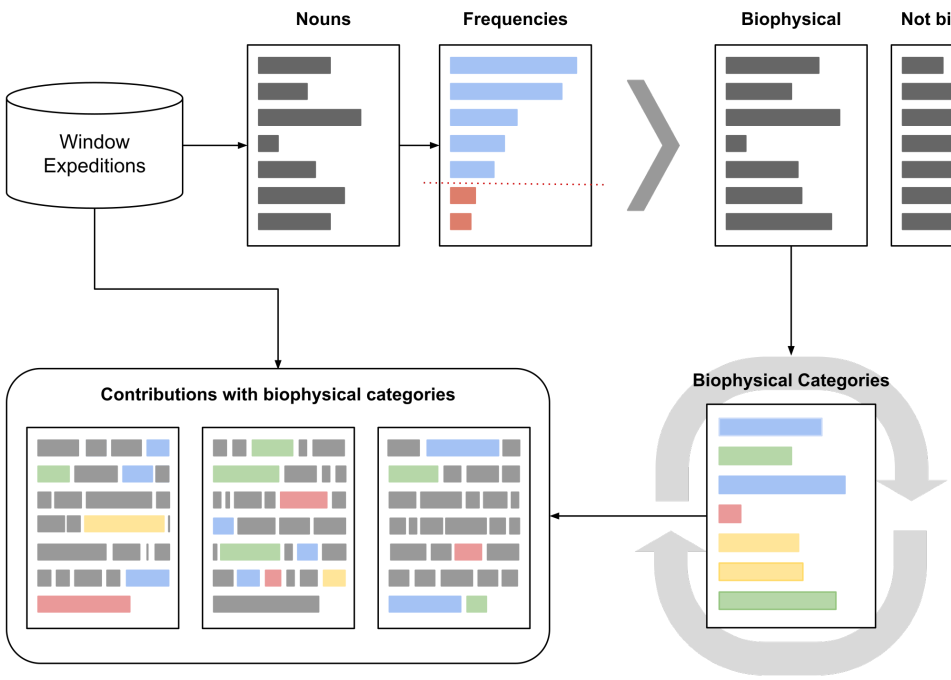


Figure 5.9: Schematic representation of annotating biophysical terms

Biophysical elements are an important dimension in cultural ecosystems studies and frameworks (cf. Bieling, 2014; Fish et al., 2016; Gould et al., 2020), however, computationally identifying biophysical elements remains challenging. Using lists of compiled signifier terms to identify landscape relevant information in natural language has proven to be a valuable approach (cf. Craik, 1972; Purves et al., 2011; Derungs and Purves, 2014; Chesnokova and Purves, 2018), hinting at the potential of compiling a list of biophysical landscape elements to be used in further research.

To identify biophysical elements in $\mathbb{WE}^{en}$ a list of biophysical noun lemmas was created in an iterative approach (Figure 5.9). Firstly, all noun lemmas (identified

Category	Abbreviation	Examples
animals	*anim*	dog, bird, squirrel
anthropogenic objects	*aobj*	football, chair, turbine
built environment	*bui*	house, building, highway, railway
building parts	*bui_part*	floor, window, balcony
land cover	*lc*	forest, driveway, farm
materials	*mat*	ground, wood, rock
moving objects	*mo*	car, boat, train
natural features	*nf*	mountain, coast, hillside
people	*peo*	people, child, neighbour
vegetation	*veg*	tree, flower, shrub
water	*wat*	water, lake, pond
weather / atmosphere	*wea*	sky, horizon, breeze, snow

Table 5.1: Table showing emergent biophysical categories and examples of signifier terms

through part of speech tagging) found four or more times in $\mathbb{WE}^{en}$ were extracted. Two researchers annotated the exported lemmas as being either a biophysical term or not. Further, the individual terms identified as biophysical elements were added to a higher order biophysical category. These categories emerged from the data through an iterative process resulting in a total of twelve categories (cf. table 5.1). Finally, the contributions were revisited and each description was complemented with the biophysical categories it contained.

5.4.2 Sensory experiences

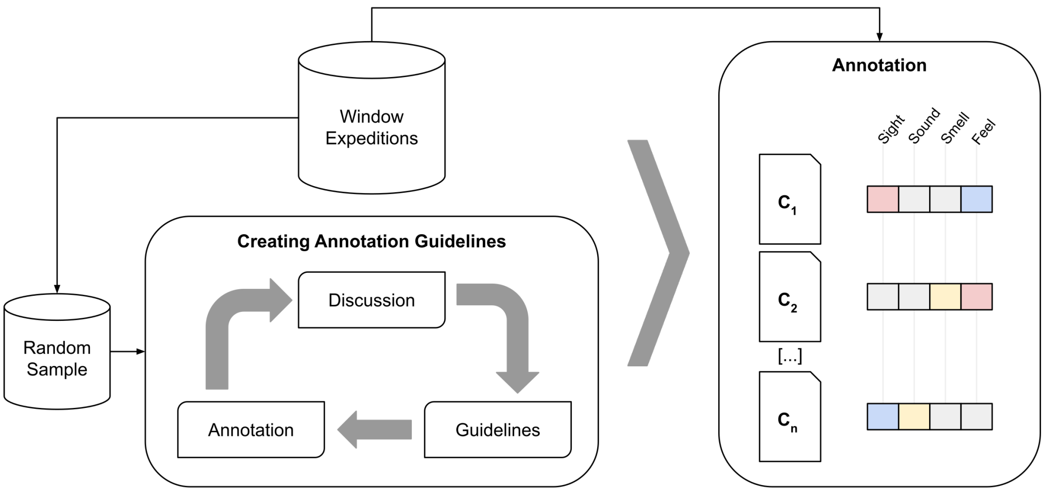


Figure 5.10: Schematic representation of annotating sensory experiences

Annotating sensory experiences calls for moving beyond extracting information using compiled lists of identifiers towards annotating contributions using annotation guidelines. In an iterative process, four researchers collaboratively created an annotation guideline document. To create the annotation guidelines, a random sample of contributions was annotated in regards to the sensory dimensions (sight, sound, smell/taste, touch/feel) they contained as well as the attitude towards respective experiences (positive, negative, neutral)(cf. Chapter 2). The resulting annotations were discussed and a first draft of guidelines was created. This process was repeated and the guidelines revised until all four researchers agreed on a final set of guidelines. Finally, one researcher annotated all landscape descriptions contributed to *Window Expeditions* using the created guidelines. The descriptions were annotated on the level of contributions resulting in every contribution containing information about the sensory experiences and the attitudes of these experiences referenced within the text (Figure 5.10).

5.4.3 Cultural ecosystem services

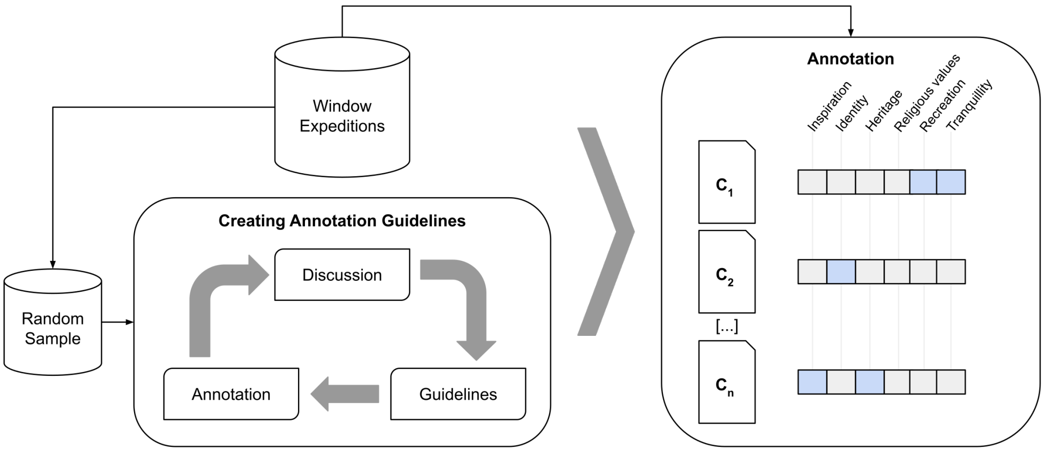


Figure 5.11: Schematic representation of annotating cultural ecosystem services

To operationalise the annotation of cultural ecosystem services, a similar approach as with annotating sensory experiences was chosen. First, a preliminary set of categories was defined. The categories were based on a combination of dimensions found in contemporary research (cf. Bieling, 2014; Fagerholm et al., 2020) which are commonly derived from the Millenium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005). The individual categories (inspiration, identity, heritage, religious values, recreation, tranquillity) are described in (Chapter 2). Similar to the workflow of annotating sensory experiences, a random sample of contributions was annotated by four researchers and the annotations were discussed. The discussions revealed potential guidelines which were compiled in a document. The annotation, discussion and guideline revision steps were repeated until all four researchers agreed on a final version of the annotation guidelines. I then used the created and approved guidelines to annotate the whole $\mathbb{WE}^{en}$ corpus. The descriptions were again annotated on the level of contributions resulting in every contribution containing information about the cultural ecosystem services referenced within the text (Figure 5.11).

5.5 Identifying similar documents

Window Expeditions successfully generated a corpus of natural language landscape relevant documents comparable in size to similar research (Bieling, 2014; Fagerholm et al., 2020). However, the dataset is rather small limiting largescale explorations of sensory experiences and cultural ecosystem services in everyday lived landscapes. I thus investigated the potential of using the generated corpus to automatically identify similar documents in other collections of natural language datasets. This would allow for a much larger high quality and landscape relevant corpus to be generated.

5.5.1 Vector representations of documents

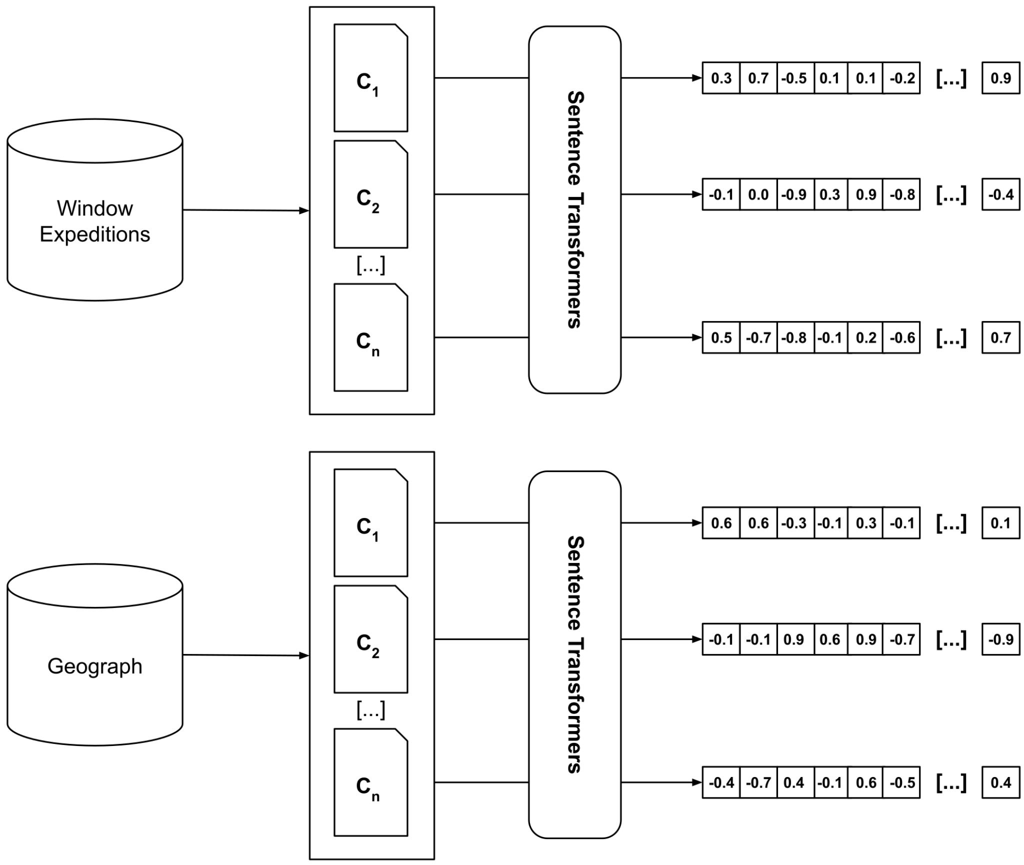


Figure 5.12: Schematic representation of translating documents to a multidimensional vector space using sentence-transformers.

The *Window Expeditions* contributions and the potentially similar Geograph documents were converted to vectors using HuggingFace's[7] sentence-transformers (Reimers and Gurevych, 2019) which are based on Bidirectional Encoder Represen-

[7]www.huggingface.co (accessed: 19.04.2022)

tations from Transformers (BERT) and use the pre-trained model *all-mpnet-base-v2*[8]. The model is based on the pre-trained model *microsoft/mpnet-base* (Song et al., 2020) which was fine-tuned using around 1 billion sentence pairs, including data from Reddit (Henderson et al., 2019), WikiAnswers[9], Yahoo Answers[10] and Flickr (cf. Young et al., 2014). Despite the chosen model truncating input texts to the first 384 tokens (word segments), the *all-mpnet-base-v2* shows highest overall performance according to the published performance metrics[11]. All *Window Expeditions* and *Geograph* documents are translated to a 768 dimensional dense vector space on which further calculations such as cosine similarity can be performed (cf. Figure 5.12).

The resulting vector representations of *Window Expeditions* contributions, and vectorised documents in general, are argued to contain the underlying semantics of the natural language texts they represent (Mickus et al., 2020; Yenicelik et al., 2020) in a multidimensional vector space (cf. Devlin et al., 2019; Liu et al., 2019). In a next step, other documents were transformed to vectors using the same model. For the approach described here, the *Geograph*[12] photo descriptions corpus was used containing around 4.5 million representative landscape images with respective descriptions. After converting all potentially similar Geograph documents (the image descriptions) to vectors, each *Window Expeditions* vector was compared to each *Geograph* vector using cosine similarity, a common approach of comparing multidimensional vectors (cf. Manning and Schütze, 1999; Singhal, 2001). Finally, all contributions were retained showing a cosine similarity above a chosen threshold. Since other datasets (such as the used *Geograph* corpus) can have many irrelevant documents, the steps above were repeated only retaining documents that contained at least one adjective found in Craik's list of landscape adjectives (Craik, 1972) or a biophysical term from the biophysical term list created as part of this thesis. To further increase the likelihood of discarding non-relevant documents, only terms occurring significantly more frequently in *Window Expeditions* than in general English were included in the aforementioned lists of signifier terms.

[8]www.huggingface.co/sentence-transformers/all-mpnet-base-v2 (accessed: 19.04.2022)
[9]www.github.com/afader/oqa#wikianswers-corpus (accessed: 19.04.2022)
[10]www.kaggle.com/datasets/soumikrakshit/yahoo-answers-dataset (accessed: 19.04.2022)
[11]www.sbert.net/docs/pretrained_models.html (accessed: 19.04.2022)
[12]www.geograph.org (accessed: 02.02.2022)

5.5.2 Cosine similarity

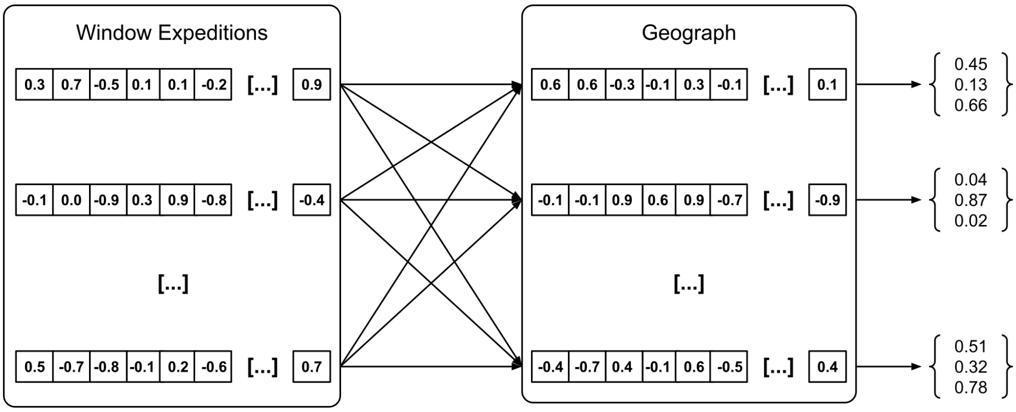


Figure 5.13: Schematic representation of calculating similarity scores between *Window Expeditions* and *Geograph*.

A popular reason for translating natural language texts to a dense vector space is the resulting ability of calculating cosine similarity scores between two vectors. Cosine similarity scores represent the angles between two given vectors and have been used for a number of natural language processing tasks such as clustering similar texts or documents and performing topic modelling to extract emergent clusters of similar topics (cf. Pennacchiotti and Gurumurthy, 2011; Boyack et al., 2011; Takano et al., 2020). Cosine similarity calculates the angle between two vectors ($\vec{A}$ and $\vec{B}$) in an n-dimensional space with the following formula:

$$cos(\theta) = \frac{\vec{A} \cdot \vec{B}}{||\vec{A}|| \, ||\vec{B}||} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2} \sqrt{\sum_{i=1}^{n} B_i^2}}$$

Where $\vec{A}$ and $\vec{B}$ are the vectors and A_i and B_i their respective components. A cosine similarity score of 0 signifies the two vectors are orthogonal and thus show no similarity, whereas a cosine similarity of 1 signifies identical vectors and thus a complete overlap (cf. Han et al., 2012; Li and Han, 2013; Wartmann and Purves, 2018). Calculating the cosine similarity scores between each of the *Window Expeditions* document vectors and the document vectors from another source (such as descriptions of representative landscape images) (Figure 5.13) allows for the identification of other documents similar to at least one *Window Expeditions* contribution.

6 Exploring the Contributions to *Window Expeditions*

> *Language is a window into human nature, but it is also a fistula, an open wound through which we're exposed to an infectious world.*
>
> — **Steven Pinker**
>
> (Linguist)

After developing and implementing *Window Expeditions* I exported and analysed the generated natural language landscape descriptions. This chapter presents who the contributors are and what the corpus captures in regards to everyday lived landscapes. Firstly, I introduce the contributors through descriptive statistics before presenting general characteristics of the locations of the contributions. In a further step I compare English and German contributions to *Window Expeditions* and discuss similarities and differences between how everyday lived landscapes are perceived as a function of language. I then compare the generated corpus to other corpora and highlight the domain specificity of the contributed landscape descriptions. Finally, I present the biophysical elements, sensory experiences and cultural ecosystem services identified within the generated corpus and the connections between these.

6.1 Characterising the crowd

The *Window Expeditions* corpus ($\mathbb{WE}$) that was exported, analysed and presented in this chapter consisted of 650 natural language landscape descriptions contributed from 43 countries or administrative regions. Most contributions were made using the English version of the application ($n = 435$), followed by German ($n = 184$) and French ($n = 31$). The contributions were moderated and a small number of obviously spurious descriptions or descriptions that seemed to be humorous spoof contributions were removed ($n = 12$). The remaining contributions analysed here ($n = 638$) were uploaded by 88 registered users who contributed 170 descriptions and 426 anonymous users who contributed 468 descriptions between 16.08.2020 and 08.02.2022. Most participants contributed once ($n = 480$) or twice ($n = 18$)

with a small number of users ($n = 4$) contributing many times (12,15,19 and 25 respectively).

To delve deeper into the questions of who the contributing users are, what demographics they represent and to explore the languages of contributors, descriptive statistics on the reported user data were explored. Knowing who contributes to a crowdsourcing project has been identified as valuable for interpreting crowdsourced data (Comber et al., 2016). However, crowdsourced datasets used in large scale landscape perception research often lack information about participants (cf. See et al., 2016; Bubalo et al., 2019), which has been observed with passively crowdsourced data in general (cf. Van Zanten et al., 2016; Oteros-Rozas et al., 2018; Ghermandi and Sinclair, 2019), making an active approach such as *Window Expeditions* a valuable addition.

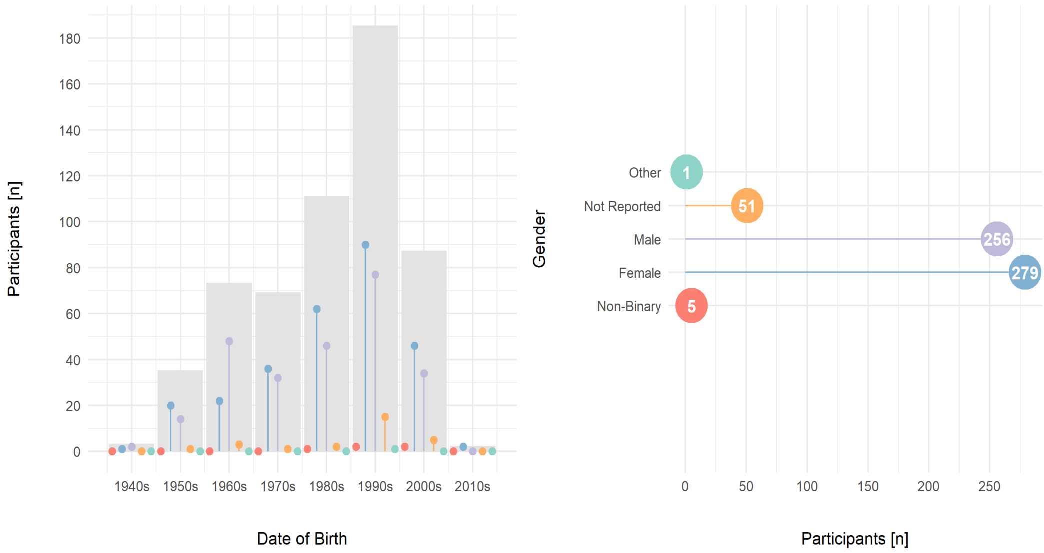


Figure 6.1: Demographics of the contributing users. Left: Year of birth distribution with bars representing the total count and lollipops the individual genders; Right: Overall gender distribution

In *Window Expeditions*, 84.8% of the contributors were adults of working ages (18 - 65 years old). Millennials were most likely to participate (Figure 6.1) reflected in the participants' median (1990) and mean (1986) year of birth. Many users chose to disclose their gender and a slightly higher number of contributions from reportedly female participants ($n = 279$) than reportedly male participants ($n = 256$) was observed (Figure 6.1). The corpus further contains five contributions from reportedly non-binary individuals, one contribution from a participant specifying their gender as other and about 10% contributed by users choosing not to report their gender ($n = 51$), the default option during the contributing process.

Window Expeditions was implemented as a multilingual application with English and German versions accessible from the beginning and a French version being added slightly later (03.12.2020). When participants upload a contribution the application language is added as meta-data. Most contributions were uploaded using the English version ($n = 426$), approximately one third uploaded using the German version ($n = 181$) and 31 participants used the French version. In addition, users were asked to state the languages they believed themselves to be fluent in (Figure 6.2). The majority of contributions ($n = 586$) contained this information of which most came from the English version of the application ($n = 398$) and users mostly reported being fluent in English ($n = 375$) followed by German ($n = 57$) and French ($n = 20$). Fewer participants used the German version of the application to upload a landscape description ($n = 157$) and almost all of these reported being fluent in German ($n = 151$) with less reporting English ($n = 85$) and French ($n = 11$). Least participants used the application in French ($n = 31$) with most reporting to be fluent in French ($n = 29$), followed by English ($n = 13$) with only one contributor reporting being fluent in German. A large number of users reported being fluent in another language ($n = 136$) pointing towards a diverse group of participants in terms of language knowledge. Then again, a rather large number of participants was identified reporting to only speak English ($n = 196$) or German ($n = 69$).

In total, a higher number of participants reported being fluent in English (76.3%) independent of the chosen application language compared to German (35.3%) and French (12%). This potentially highlights users overestimating their knowledge of the English language or English being a common global language. Over all, English was reported by most participants ($n = 473$), followed by German ($n = 209$), French ($n = 60$), Spanish ($n = 42$) and Italian ($n = 15$).

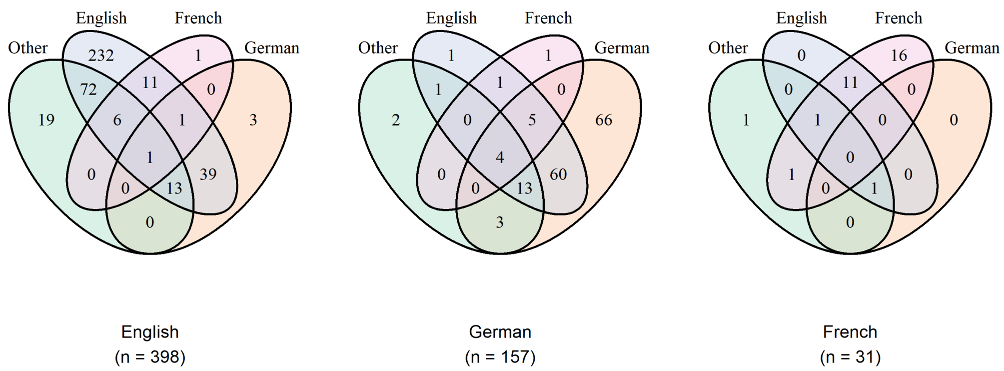


Figure 6.2: Number of contributions in each application language and user reported language combinations. Left: English; Middle: German; Right: French

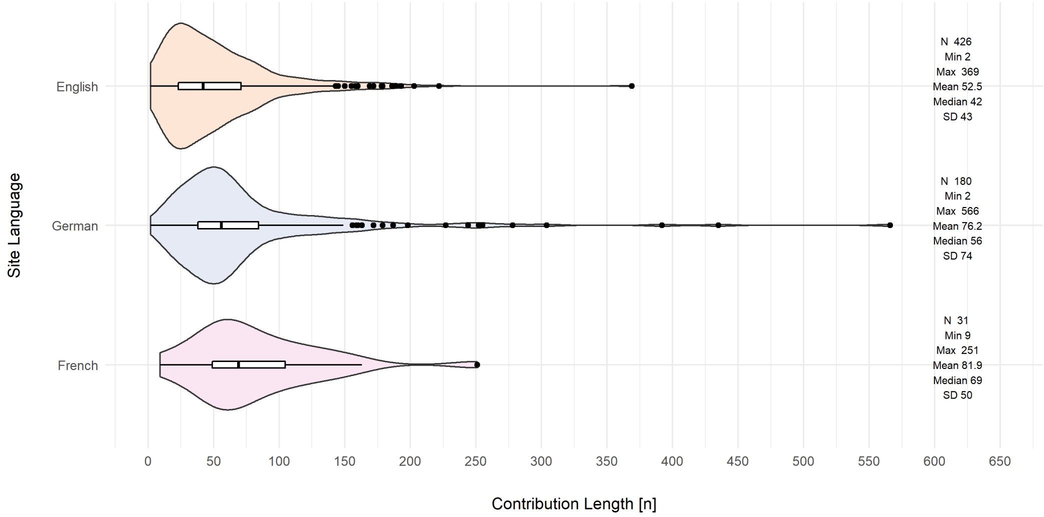


Figure 6.3: Application language and respective contribution lengths in terms of number of words

The results showed a small but significant (Wilcoxon rank sum test with continuity correction; $p < 0.01$) difference in the length of English and German contributions (Figure 6.3) with contributions uploaded through the English version being shorter in terms of words than contributions uploaded through the German version. Contributions to the French version of the application were longest on average, however, given the small number of contributions, no significance testing was performed.

> *Window Expeditions* successfully motivated a gender balanced audience of young to middle aged participants, many of whom reported being fluent in multiple languages.

6.2 Characterising the locations of contributions

This section reports on comparing the locations of *Window Expeditions* contributions with the land cover types of Copernicus (Buchhorn et al., 2020) (cf. Chapter 5). The results show that the vast majority of contributions were made from urban and built up areas (55.7%) followed by herbaceous vegetation (11.9%), open forest unknown (8.4%) and cultivated and managed vegetation or agriculture (7.5%) (Figure 6.4). These land cover types are typically found in residential areas or local recreational areas (cf. Zipperer et al., 1997; Schubarth and Weibel, 2013; Nielsen and Jensen, 2015). This supports the hypothesis that participants did indeed contribute from home. To further investigate the locations of participants, the dataset was stratified depending on if users reported being at home ($n = 466$) (Figure 6.4) or not ($n = 172$) (Figure 6.4). By comparing the land cover types of these two subsets a statistically significant (Wilcoxon signed rank exact test; $p < 0.01$) difference was found in the distribution of land cover types. Contributions from participants who reported being at home were found more often in urban and built up areas (57.8%) and less likely to be in areas of herbaceous vegetation (10.4%) compared with contributions from users who reported not being at home (49.9% and 16% respectively). These findings strengthen the hypothesis that *Window Expeditions* successfully motivated participants to contribute from home and describe their everyday lived landscapes.

> *Window Expeditions* successfully motivated participants to participate from home and captures in-situ experiences of everyday lived landscapes.

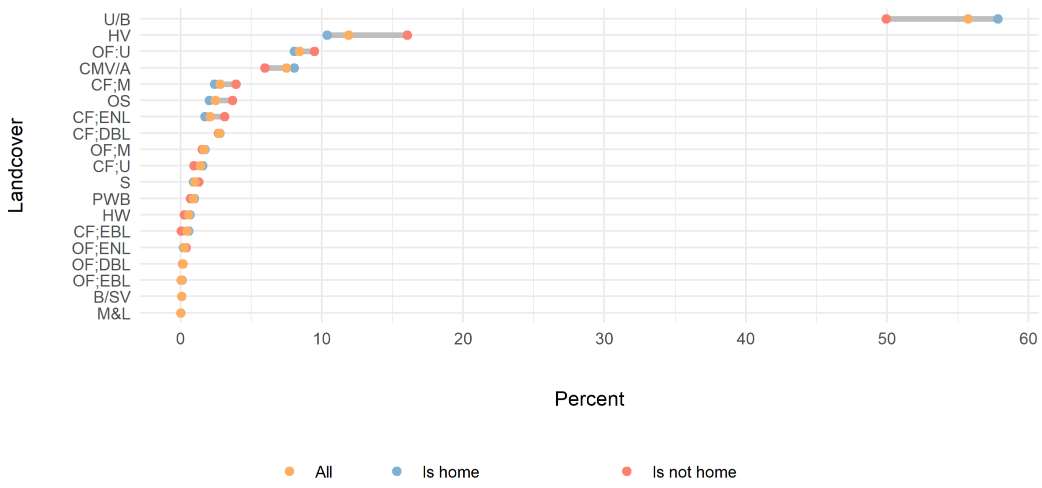


Figure 6.4: Distribution of land cover classes for users reporting being at home, users reporting not being at home and all users combined. **Classes:** *Urban / built up (U/B); Herbaceous vegetation (HV); Open forest, unknown (OF:U); Cultivated and managed vegetation / agriculture (cropland) (CMV/A); Closed forest, mixed (CF;M); Open sea (OS); Closed forest, evergreen needle leaf (CF;ENL); Closed forest, deciduous broad leaf (CF;DBL); Open forest, mixed (OF;M); Closed forest, unknown (CF;U); Shrubs (S); Permanent water bodies (PWB); Herbaceous wetland (HW); Closed forest, evergreen, broad leaf (CF;EBL); Open forest, evergreen needle leaf (OF;ENL); Open forest, deciduous broad leaf (OF;DBL); Open forest, evergreen broad leaf (OF;EBL); Bare / sparse vegetation (B/SV); Moss and lichen (M&L)*

6.3 Comparing English and German *Window Expeditions* contributions

The contributions in different languages were compared and interpreted using natural language processing and translation workflows (cf. Chapter 5). The results were visualised with lists of terms in both English and German ordered by frequency rank and linked to their respective translations (Figure 6.5 - 6.7). Given the small number of contributions to the French version of *Window Expeditions* ($n = 31$) compared to

English ($n = 426$) and German ($n = 181$) I excluded French from further analyses. The English and German corpora of *Window Expeditions* contributions are referred to as $\mathbb{WE}^{en}$ and $\mathbb{WE}^{de}$ in the remainder of this chapter.

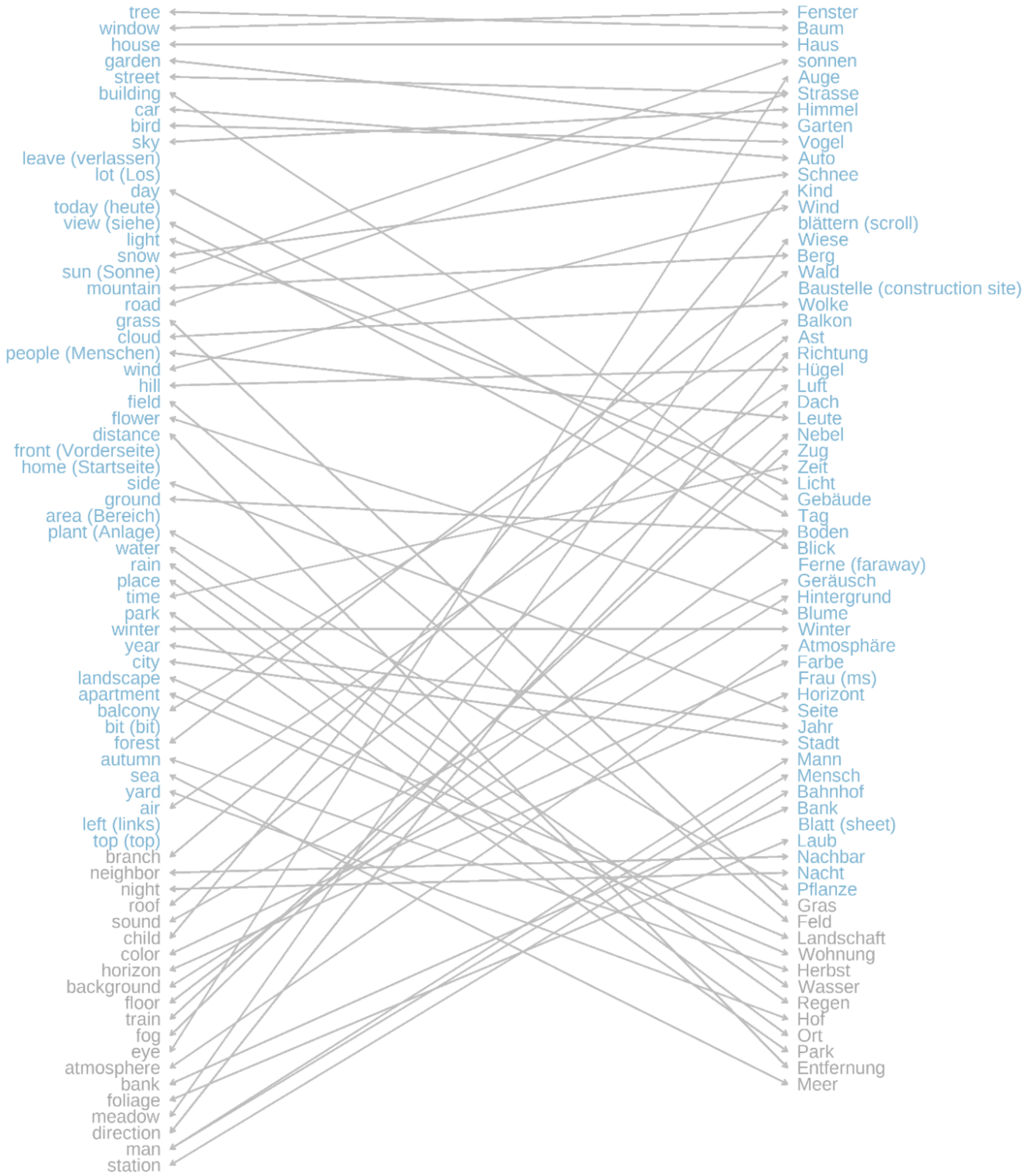


Figure 6.5: Comparing the most frequent English and German noun lemmas

Firstly, the most frequent nouns in both the $\mathbb{WE}^{en}$ as well as $\mathbb{WE}^{de}$ corpora were plotted and compared. Some terms were found to be prominent in both languages (e.g. "*window / Fenster*", "*tree / Baum*", "*house / Haus*", "*garden / Garten*" and "*street / Strasse*") pointing towards some commonality in salient landscape features independent of language. The frequent occurrence of the term "*window / Fenster*" is most likely due to *Window Expeditions* specifically incentivising participants to describe what they perceive from their windows. As such, many participants used the term "*window / Fenster*" to describe their point of view (cf. Example 6.1).

Example 6.1
When I look out of the window, I see an empty campus. The sidewalks are empty, autumn leaves scattered around. The last rays of autumn sunlight are trickling through the trees onto a well kept (and still green) but empty lawn in front of the Aula.

The terms *"tree / Baum"*, *"house / Haus"*, *"garden / Garten"* and *"street / Strasse"* describe important features of everyday lived landscapes and shed light on the elements that are particularly salient (cf. Example 6.2). These terms show considerable differences to other studies investigating landscapes where commonly the terms "mountain / Berg" and "sea / Meer" or other bodies of water appeared frequently (cf. Mark et al., 1999; Wherrett, 2000; Edwardes and Purves, 2007; Wartmann et al., 2018; Wartmann and Purves, 2018; Fagerholm et al., 2020). In our corpus anthropogenic infrastructure such as houses, buildings and streets as well as natural features typically found in urban and suburban settings were most common. The importance and saliency of anthropogenic objects has also been found in landscape specific data collections such as Geograph (Edwardes and Purves, 2007), a collection of representative landscape images including descriptions and tags. This strengthens the hypotheses that participants contributed from home and predominantly described perceived elements of everyday lived landscapes.

Example 6.2

- The driveway is clean, few leaves on the ground. There are quite a few trees in the front yard, and a good amount of bushes. The front yard looks very neat and I can see my neighbors across the street.
- My building is surrounded by trees and other houses. For one of the sides (the window of the kitchen and two of the rooms), I can see other building blocks and its garden, a portion of the 31th street, and also trees. Through the balcony and two other bedrooms I can see the parking spots within the unit, other houses of this building block, and more trees.

Some terms potentially highlight differences in what is perceived depending on the language or location of the participant. For example, in $\mathbb{WE}^{de}$ the terms *"Nebel" ("fog")* and *"Luft" ("air")* appear considerably more frequently than in $\mathbb{WE}^{en}$ (Figure 6.5). This could hint at meteorological terminology being more important in German speaking areas due to more subtle differences in weather conditions (e.g. terms for different types of fog in German such as *"Nebel / fog"* and *"Hochnebel / high fog"* (cf. Example 6.3)), or a different vocabulary being important in describing meteorological or climatic phenomena in English. It could also be related to the general use of language where in English participants might be prone to say *"it's a foggy day"* where *"foggy"* would be identified as an adjective and not a noun by the part of speech tagging. Further, the term *"meadow / Wiese"* is found considerably more frequently in $\mathbb{WE}^{\text{de}}$ than in $\mathbb{WE}^{\text{en}}$ suggesting the concept to be more salient in the German language compared to English. On the flipside, the terms *"field / Feld"* and *"grass / Gras"* appear more frequently in the $\mathbb{WE}^{\text{en}}$ corpus, supporting the argument that different terminology is used to describe similar landscape features in different languages.

The results point to two important issues in computationally analysing multilingual corpora: firstly, the results of machine translation services depend on how these were trained (e.g. the English term *"plant"* being translated to *"Anlage"*, as in a *"power plant"* or the English term *"home"* being translated to *"Startseite"*, as in *"home page"*). This points towards the underlying translation model being trained on web based or technical corpora and highlights the influence of the internet on translation services. Further, terms such as *"landscape"* encompass large culture specific concepts and can only loosely be translated to other languages such as German (*"Landschaft"*) and French (*"paysage"*) (cf. Olwig, 1996; Antrop, 2005; Fairclough et al., 2018; Putten et al., 2020). Secondly, part of speech tagging algorithms may produce different results as a function of language and convention (e.g. tagging the term *"today"* as a noun or an adverb).

Example 6.3
Alle hassen den Hochnebel, den ich von meinem Fenster beobachten kann. Der graue Topfdeckel, der Schild zwischen der Sonne und uns, er trägt viele Namen. Aber mir gefällt er. Der graue Hochnebel und die etwas hellere Oberfläche des Sees ergänzen sich ganz gut und wenn man genau hinsieht, erkennt man, dass Hochnebel und Seeoberfläche am Rande des Sichtfeldes ineinander übergehen. Ich sehe quasi nur einen Ausschnitt der Welt, umrahmt von grauem Wasser in verschiedenen Aggregatszuständen. Wenn man die Augen ein wenig zusammendrückt, hat man ein wunderschönes Gemälde in den Farben blau, grau, grün und weiss vor sich, das in der Luft zu schweben scheint wie das Hallelujah Gebirge aus Aufbruch nach Pandora. Und das ganz ohne Sonne.

In a next step, the most frequent adjectives in both $\mathbb{WE}^{\text{en}}$ as well as $\mathbb{WE}^{\text{de}}$ were plotted and compared (Figure 6.6). The results show adjectives describing size (e.g. *"small / klein; kleine"* and *"large / gross; grossen; grosse"*) as well as colours (e.g. *"green / grün; grüne"* and *"blue / blau"*) being prominent in both $\mathbb{WE}^{\text{en}}$ and $\mathbb{WE}^{\text{de}}$. This suggests that the size and colours of features are particularly important in everyday lived landscapes to describe anthropogenic features or as a way of highlighting a feature as contrasted from the general setting (cf. Example 6.4). It may also indicate that adjectives describing size and colour are common in the languages represented within the analysed corpora (cf. Lengen, 2015; Sadeghifar et al., 2019; Neale et al., 2021). In addition, it is worth pointing out that many colours show similar ranks in both languages, suggesting the saliency of colours or the presence of colours in landscapes to be similar in both English and German.

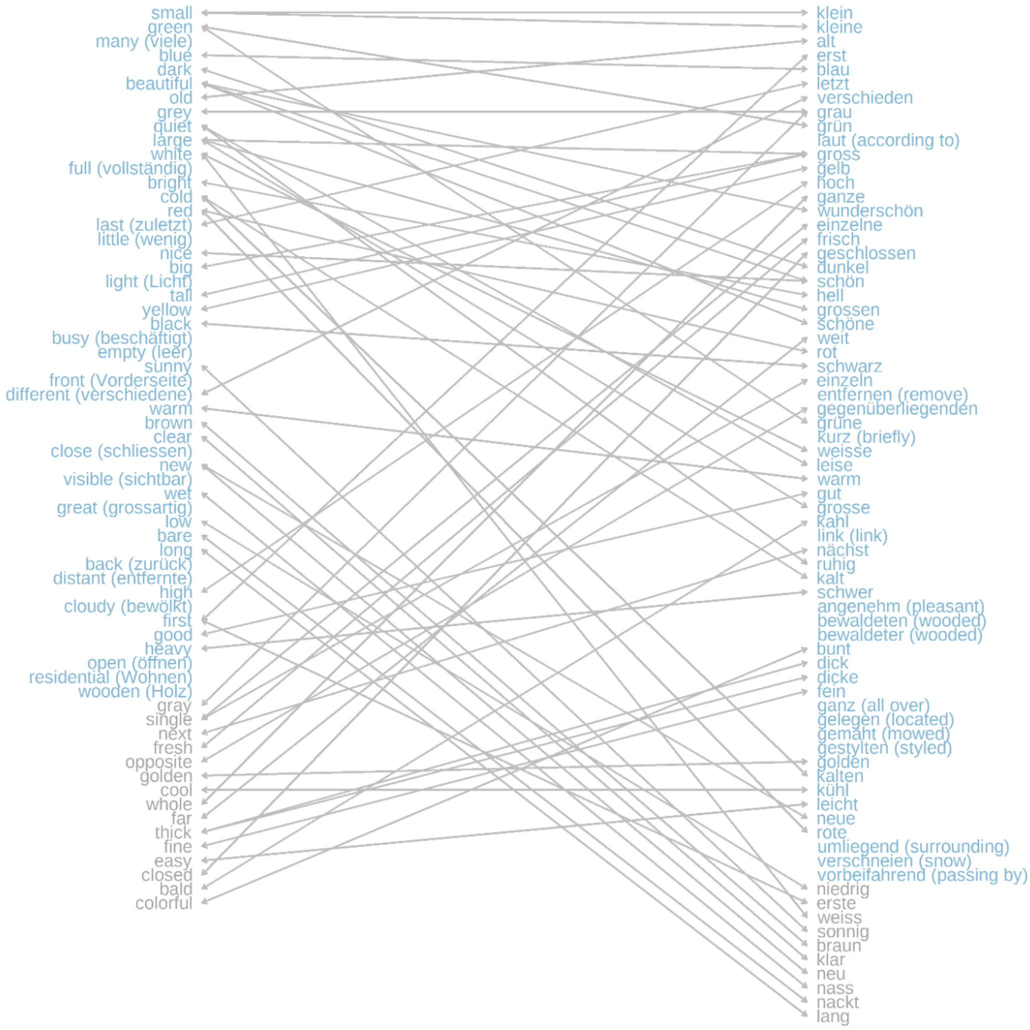


Figure 6.6: Comparing the most frequent English and German adjective lemmas

To further investigate the correlation between frequently mentioned colour lemmas, the colours and their frequencies were extracted and a significant correlation (Spearman's rank correlation rho: $rho = 0.89$; $p < 0.01$) was found between the order of the used colour lemmas in both languages. However, no significant correlation in the frequencies of colour terms was found compared to the $\mathbb{BNC}$ (Spearman's rank correlation rho: $rho = 0.35$; $p : 0.36$) or the $\mathbb{GEO}$ corpora (Spearman's rank correlation rho: $rho = 0.6$; $p : 0.1$). This suggests that the frequency in which colours are mentioned in contributions of *Window Expeditions* is stable across languages and specifically related to properties of everyday lived landscapes. Another noteworthy frequent term is *"quiet / leise; ruhig*") which is found frequently in $\mathbb{WE}^{en}$ as well as $\mathbb{WE}^{de}$ (especially if the German terms are combined). This term is frequently found in contributions hinting at perceived tranquillity or describing the noticed absence of sound (cf. Example 6.4).

The $\mathbb{WE}^{\text{en}}$ corpus shows quantifying words to be very frequent (e.g. *"few / wenige"*, *"many / viele"*) which seem to be missing in $\mathbb{WE}^{\text{de}}$. This difference can be traced back to the used lemmatisation and part of speech tagging algorithms producing different results for English and German terms (e.g. adjective vs. adverb). The results also show a notable number of terms with multiple connections compared with the most frequent nouns. The rank-list shows the English terms *"nice"* and *"beautiful"* were both translated to the German term *"schön"*, whereas the German terms *"wunderschön"*, *"schön"* and *"schöne"* were translated to the English term *"beautiful"*. These results again show the limits of computationally analysing natural language as a human annotator would intuitively combine the mentioned German terms to the unifying lemma *"schön"*.

Example 6.4

- Looking out over a fairly typical Dutch neighborhood backyard. 2-storey terraced houses, small gardens and sheds. Houses are quite varied, of mixed sizes and from different time periods. Many of the small gardens don't have lawn but hard surface, but still lots of green (shrubs, trees). Now it's autumn and the sun is shining (for a change), so lots of beautiful colors. Several smaller birds and some pigeons and ravens are around.
- This is a medium density (by Australian standards) inner-city suburb. Rows of town-houses, with small back yards, and garages. Unlike most others, it is very green. Beautiful gum trees, as well as plane trees line maintained public lawns and playgrounds. Magpies sing in the tress today, as well as pesky minas (introduced, pest species). But they are lovely, enjoying the refreshed greenery after a night of rain. A rare green pocket so close to the center of a world metropolis. A river snakes through - these days the banks are busier than the city center, with runners, cyclists and children. An urban wetland has been our destination all through COVID, everyone monitoring the growth of Black Swan cygnets. A lovely place to be, if you are restricted to 5kms from home. All this is, however, not visible from my window - my office, for the last half year, is a windowless nook. It is good to know that I can just walk out, and hang a hammock or a slackline between the trees. metres from my front porch.
- The trees have spanish moss on them, so it looks like a party is happening, and it smells like gardenias and jasmine. It's hot out, but it is really quiet and the ground is sandy.
- I see a quiet Main Street with a bed and breakfast across the street. There are many american flags and porches. The houses are old, they were built in the 1800s. They are made out of wood or stone. There are mountains in the distance.

Finally, the most frequent verbs in the $\mathbb{WE}^{\text{en}}$ and $\mathbb{WE}^{\text{de}}$ corpora were plotted and compared. Here we find terms related to sensory experiences such as *"see / sehen"*, *"look / schauen; blicke"*, *"hear / hören"* and *"feel / spüren; fühlen"* to be common (Figure 6.7). This is no surprise seeing the multilingual corpus of natural language descriptions revolve around how we perceive our immediate surroundings. Many contributors use mentioned terminology to describe how they perceived certain salient features of their surroundings. Other terms with similar ranks in both $\mathbb{WE}^{\text{en}}$

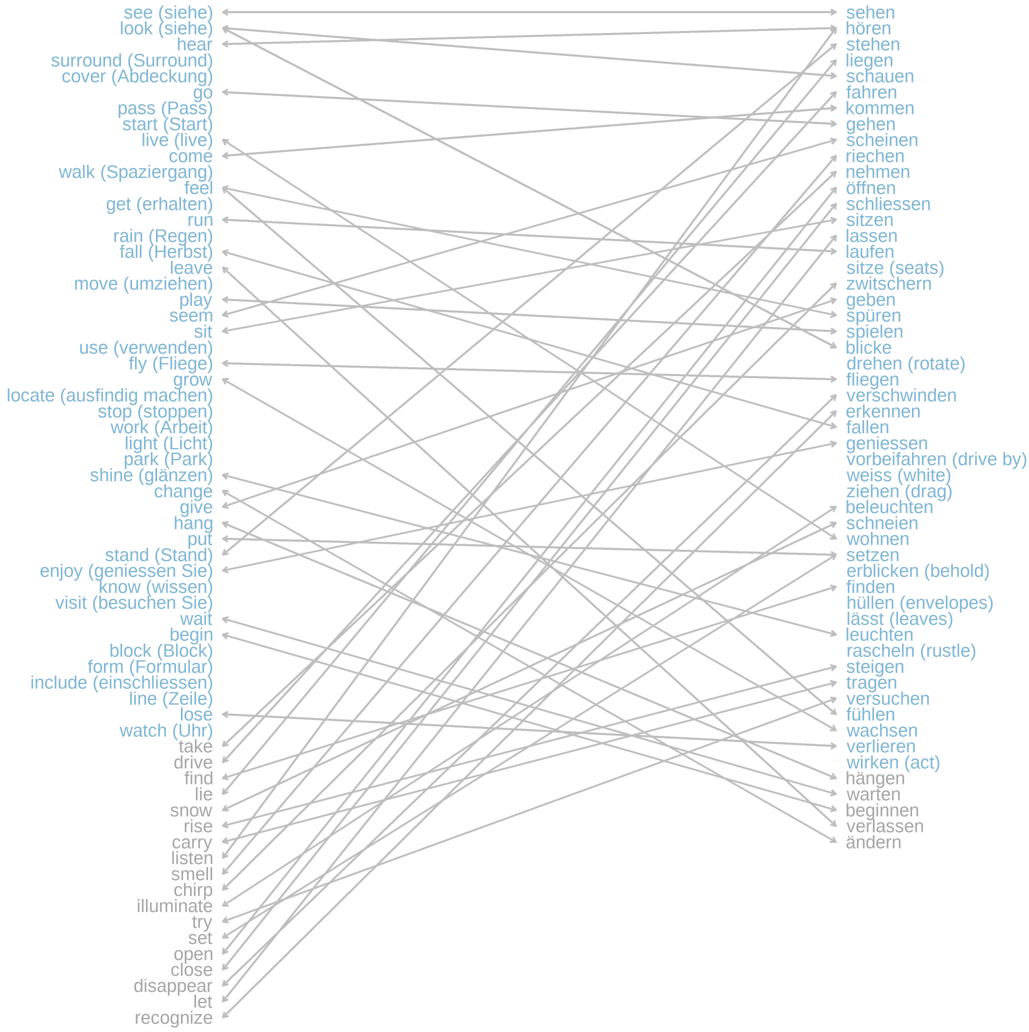


Figure 6.7: Comparing the most frequent English and German verb lemmas

and $\mathbb{WE}^{de}$ include terms describing some form of movement (e.g. *“go / gehen”*, *“come / kommen”*, *“run / laufen”*, *“play / spielen”* and *“fly / fliegen”*). These generally refer to observed moving objects (e.g. cars), moving people (e.g. playing children) and moving fauna or flora (e.g. flying birds) (cf. Example 6.5).

Interestingly, the term *“smell / riechen”* is highly frequent in the $\mathbb{WE}^{de}$ corpus but scarce in the $\mathbb{WE}^{en}$ corpus. This could suggest smells being more important in the perception of landscapes in German speaking regions or that English speaking participants use the term *“smell”* as a noun opposed to an adjective to describe the olfactory perception of their surroundings.

Example 6.5

- Nowadays mostly working from home. I don't go outside much. Vaccination has started in India. Hopefully situation will get better soon and we can enjoy our surroundings again.
- I like to see the calm street and the colourful houses through the branches of the big trees that are in front of my window. I like to be aware of the changing colours of the leaves and the different birds that come and go at different times of the day. I also like that there is space between the buildings so I can see a bit in the distance the roof and trees from the other houses far away. I like that is diverse both in terms of types of vegetation and houses. Uglier or prettier the all have their own character.
- Beautiful beach! I like to run along this beach with my eyes shut at half tide and listen to the waves and birds. Feels so surreal. Other times we play here with a ball or frisbie on the big open golden sandy space. It's quite flat, not too steep but does have some rocks at the east and west sides which are good to explore with the kids.
- Lots of sandstone rocks make up the college campus. Lots of large oak trees with black squirrels running around the roots. It's cold and wet. Cardinals and robins fly and hop around. They are singing. Old acorns litter the ground. They have mostly lost their caps or are in pieces, after all, it is spring.

The contributions to *Window Expeditions* show nouns associated with everyday lived landscapes (e.g. house, tree, garden, street), adjectives describing size and colour (e.g. small, large, green, blue) as well as verbs associated with sensory experiences (e.g. see, look, hear, feel) to be frequent in both English and German. Terms that were more frequent in one language revealed subtle differences in salient landscape characteristics depending on the user's location (e.g. weather related terminology) and that computational approaches produce varying results depending on the parsed language.

6.4 Comparing *Window Expeditions* contributions to other corpora

To investigate the domain specificity of the $\mathbb{WE}$ corpus collected through *Window Expeditions* I compare the natural language descriptions contributed to the English version of the application ($\mathbb{WE}^{en}$) with a corpus representing general English ($\mathbb{BNC}$) (Kilgarriff, 1995) and a further corpus of representative landscape image descriptions ($\mathbb{GEO}$) (cf. Chesnokova and Purves, 2018). The $\mathbb{BNC}$ corpus, consisting of a list of term lemmas, part of speech types and frequencies, was downloaded and imported. A random subset of 50000 image descriptions of the $\mathbb{GEO}$ corpus was annotated using the same natural language processing workflow used to parse $\mathbb{WE}^{en}$ (cf. Chapter 5). The three corpora were compared using χ^2 statistical testing to identify particularly salient term lemmas and the results were visualised as word clouds (cf. Chapter 5).

The results show frequent noun lemmas in 𝕎𝔼^{en} (e.g. *"tree"*, *"window"*, *"house"*, *"bird"*, *"building"*) differ from both English in general found in 𝔹ℕℂ or more general landscape descriptions found in 𝔾𝔼𝕆 (Figure 6.8). This suggests the actively crowd-sourced landscape descriptions collected through *Window Expeditions* reveal project specific semantics about everyday lived landscapes.

Figure 6.8: Wordcloud of most frequent noun lemmas found significantly more in 𝕎𝔼^{en} than in 𝔹ℕℂ and in 𝔾𝔼𝕆

Example 6.6
I'm sitting on an old, wooden bench below the nurturing crown of an ancient beech tree on the edge of a hill. Behind me, a hidden plateau with old-growth forest stands guard. In front of me a beautiful valley spreads out Some fields of rapeseed crops but mostly blooming meadows abound, filled with the buzzing of bees and other winged being's sound. The grass has not yet been cut for hey- a soundless breath escapes my lips "oh,what a beautiful day". Two delicate butterflies dance closely by entangled in their own little world of careless play I see flowers in hues of yellow and pinks and purples and blue, grazed by happy cows and a small goat herd too. Rolling hills of Jurassic age stretch across the horizon in the West, and white, puffy clouds slowly chase one another across a canvas of blue Far in the South I see a lake's waters glitter and sparkle under a sun-kissed sky like a billion diamonds on turquoise velvet it catches my eye Its soft waves break on reed shores a little sanctuary where fish find shelter and many birds safely build their nest. I see, but don't hear, little villages scattered as dots of white and brown and grey. Near and far country roads wind their way across this little slice of heaven- so inviting to the keen hiker's heart. Birds all around chant songs of spring a concert no human voice could sing. Wind softly caresses the leaves of grasses and bushes and trees a gentle rush that ebbs and flows. And as I close my eyes the gentle breeze whispers tales of far'way places into my ears. Strands of my hair now free, bounce around in joyful glee. I look up just in time, to see a red kite soar and climb high up into into the sky's endless space- the embodiment of dignity and grace. He is a king of kings a watchful guardian of this place. Taking in all these sights, and smells and sounds I relish in the marvels of nature abound. I am at ease now, yet fully aware- my body and mind have turned into a calm and peaceful state. The old, wooden bench remains steady beneath my resting hand, as my heart and soul connect to the life of this blessed land.

Figure 6.9a presents noun lemmas found significantly more frequently in $\mathbb{WE}^{en}$ than in $\mathbb{BNC}$ but not in $\mathbb{GEO}$. The results reveal nouns commonly related to spatial scenes or geographic objects such as *"view"*, *"area"*, *"city"*, *"farm"*, *"beach"* and *"lake"*. These terms show that the language captured through *Window Expeditions* is specifically geographic (cf. Example 6.6). Figure 6.9b on the other hand presents lemmas found significantly more frequently in $\mathbb{WE}^{en}$ than in $\mathbb{GEO}$ but not in $\mathbb{BNC}$. The results show noun lemmas related to time (e.g. *"time"*, *"week"*, *"night"*, *"moment"*, *"minute"*, *"weekend"*) and people (e.g. *"people"*, *"child"*, *"friend"*, *"daughter"*, *"parent"*) to be significantly more frequent in $\mathbb{WE}^{en}$ than $\mathbb{GEO}$. This demonstrates that contributions to *Window Expeditions* emphasise both the actors in everyday lived landscapes as well as the times at which these actors were observed. Terms related to people are less common in $\mathbb{GEO}$ which is more geared towards descriptions of the physical environment.

The same approach was used to create word clouds for verb and adjective lemmas (Figure 6.10). Only lemmas found significantly more in $\mathbb{WE}^{en}$ than both $\mathbb{BNC}$ and $\mathbb{GEO}$ were plotted and inspected. The results show two noteworthy points: firstly, the verbs contain common terms associated with sensory experiences (*"see"*, *"hear"*, *"feel"* and *"smell"*). This suggests that the $\mathbb{WE}^{en}$ corpus does indeed capture how participants perceive their surroundings. Secondly, the adjectives contain many terms

(a) Wordcloud of most frequent noun lemmas found significantly more in $\mathbb{WE}^{\text{en}}$ than in $\mathbb{BNC}$ but not $\mathbb{GEO}$

(b) Wordcloud of most frequent noun lemmas found significantly more in $\mathbb{WE}^{\text{en}}$ than in $\mathbb{GEO}$ but not $\mathbb{BNC}$

Figure 6.9: Wordcloud of most frequent noun lemmas found significantly more in $\mathbb{WE}^{\text{en}}$

(a) Wordclouds of most frequent verb lemmas found significantly more in $\mathbb{WE}^{\text{en}}$ than in $\mathbb{BNC}$ and $\mathbb{GEO}$

(b) Wordcloud of most frequent adjective lemmas found significantly more in $\mathbb{WE}^{\text{en}}$ than in $\mathbb{BNC}$ and $\mathbb{GEO}$

Figure 6.10: Wordclouds of most frequent verb and adjective lemmas found significantly more in $\mathbb{WE}^{\text{en}}$

related to the size (*"small"*, *"big"*, *"little"*, *"tall"*), position (*"front"*,*"back"*,*"distant"*) and colour (*"green"*, *"blue"*, *"grey"*, *"brown"*, *"white"*, *"red"*, *"black"*, *"pink"*, *"golden"*, *"orange"*) of features as well as terms associated with weather (*"sunny"*, *"bright"*, *"calm"*, *"fresh"*, *"warm"*, *"hot"*, *"cold"*) and tranquillity (*"peaceful"*, *"calm"*, *"quiet"*). This hints at *Window Expeditions* capturing what people perceive in their surroundings, how these features are described in terms of their spatial configuration and the emotional response to specific features (cf. Example 6.6). In addition, the results suggest that weather contributes to the perception of landscapes. This is in line with the literature arguing that varying weather changes our perception of landscape features (cf. Ingold, 2005). In addition, as was found when comparing English and German contributions to *Window Expeditions* (cf. Section 6.3), colours seem to be an important part of perceiving and communicating landscape elements, such as the changing of seasonal colours (cf. Tuan, 1975).

Example 6.7
There is a big old pine tree next to the window, I can only see part of the trunk and a few branches. A maple tree next to it has fresh leaves and the sunlight of the morning is dotting them. I see the neigboring house and its parking lot with cars and bikes, and a lady walking slowly across the yard. A portion of the blue sky is visible, and so is a tiny glimpse of the quiet road, with cars parked on the side. Pollen and maybe petals from the flowers in a bird cherry tree that I can see in the right corner of my window are floating in the air.

To further investigate the context of the most common terms that are significantly more common in $\mathbb{WE}^{en}$ than $\mathbb{BNC}$ and $\mathbb{GEO}$ (*"tree"*, *"view"*, *"people"*), subgraphs of the terms were built and analysed (Figure 6.11 - 6.14). The individual term lemmas represent the nodes of the graph and their syntactic relationships build the edges. The syntactic relationships were identified using the natural language processing library SpaCy. For the term *"tree"* only nodes with two or more connections were plotted, for *"view"* and *"people"* all connections are shown. The term *"tree"* is regularly connected to the type (e.g. *"evergreen"*, *"deciduous"*) and sort (e.g. *"pine"*, *"apple"*, *"birch"*, *"cherry"*, *"chestnut"*, *"maple"*, *"oak"*, *"palm"*, *"pine"*, *"spruce"*, *"walnut"*) of tree (Figure 6.11). The corpus thus reveals information about subordinate terms contributors use to differentiate and describe trees in their immediate surroundings (cf. Example 6.7), further specifying basic levels (Tversky and Hemenway, 1983). The graph further shows the term tree being highly connected with adjectival modifiers related to their appearance (e.g. *"sad"*, *"old"*, *"leafless"*, *"green"*, *"beautiful"*, *"bare"*) and their quantity and size (e.g. *"small"*, *"tall"*, *"more"*, *"many"*, *"large"*, *"few"*, *"big"*). When comparing the natural term *"tree"* with the highly frequent anthropogenic term *"building"* (Figure 6.12), the results show that users also tend to describe the type of building (e.g. *"residential"*, *"apartment"*, *"block"*, *"complex"*, *"dorm"*, *"house"*, *"office"*, *"industrial"*) as well as make references to age (e.g. *"old"*, *"new"*, *"modern"*). This points to two interesting observations of how users describe everyday lived landscapes. Firstly, common features that are omnipresent in everyday lived landscapes such as trees and buildings are detailed using subordinate terms to further differentiate the features from their general settings, independent of the feature being natural or anthropogenic. Secondly, for anthropogenic features such as buildings the material and age seem to be important, whereas natural features such as trees are described through their appearance, size and quantity.

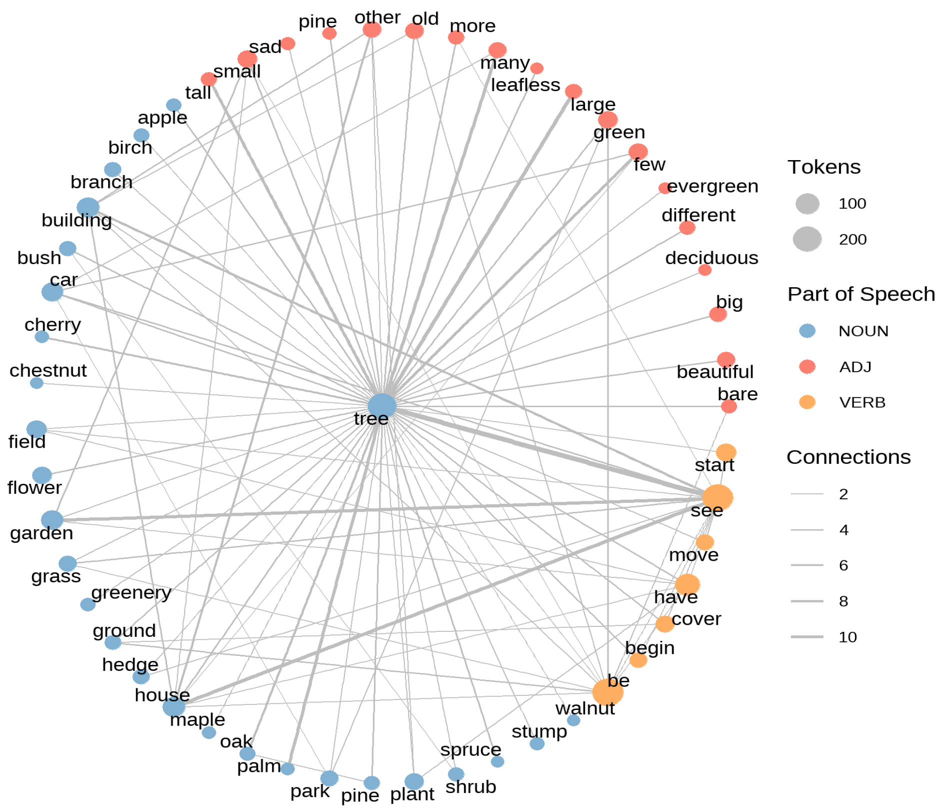


Figure 6.11: Subgraph of the lemma "*tree*"

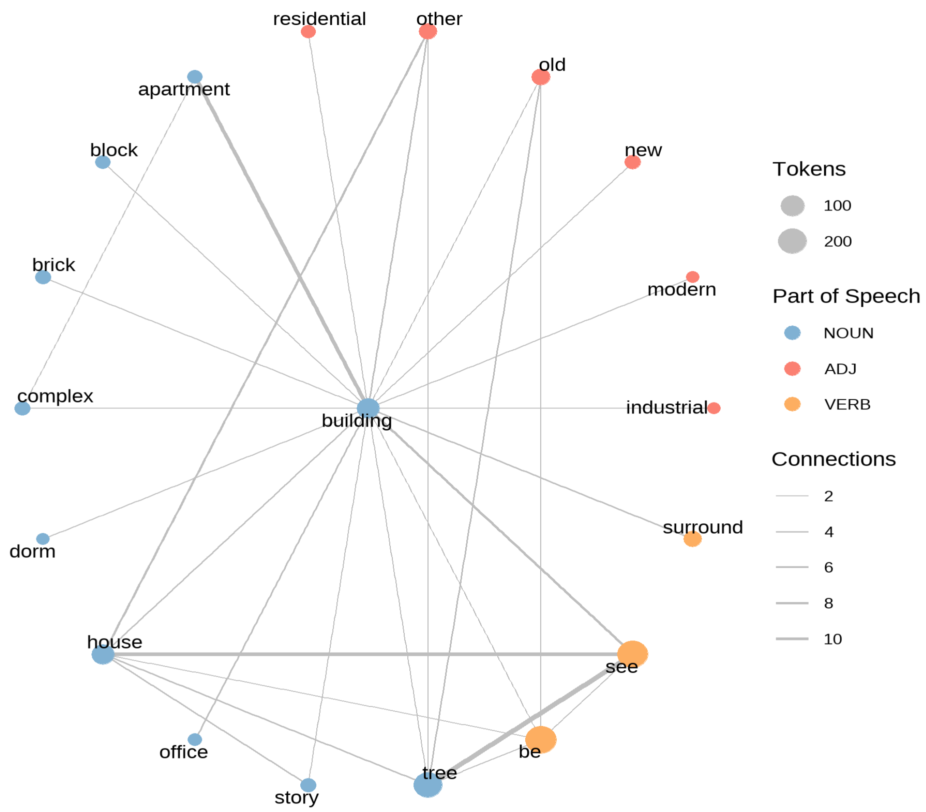


Figure 6.12: Subgraph of the lemma "*building*"

Example 6.8
I have a superb and uninterrupted view of Moel Siabod, and the outlines of other Snowdonia hills behind, from windows at the front. Today the hill was snow capped and at dawn it was highlighted with a pink sky backdrop. This being Wales the view is occasionally totally obscured by clouds. Sometimes the clouds are down in the valley over Betws-y-Coed whereas the surrounding hills are clear. Out the back I just have an upward sloping field, but the interest therein varies with the season. Spring is best when the lambs are gambolling. In autumn there are mini starling murmurations and I'm always enchanted by a visit by Red Kites at any time.

Descriptions containing the term *"view"* commonly describe the visual scenery of their immediate surroundings (cf. Example 6.8). The term "*view*" (the most frequent term found significantly more often in $\mathbb{WE}^{en}$ than in $\mathbb{BNC}$ but not in $\mathbb{GEO}$) is frequently connected to emotionally connotated terms (e.g. *"superb"*, *"spectacular"*, *"soothing"*, *"scenic"*, *"nice"*, *"great"*, *"bleak"*) as well as the vantage point and field of view of the contributor (e.g. *"vast"*, *"full"*, *"elevated"*, *"situate"*, *"obscure"*, *"block"*) (Figure 6.13). This suggests that the notion of having a view is related to high visibility and induces a certain emotional response. *"Ocean"* is the only biophysical landscape feature that shows a high number of connections with the term *"view"*, hinting that a view of the ocean is a particularly salient feature of everyday lived landscapes, dependent on location. This is in line with the literature which has found water bodies to be particularly salient in people's perception and appreciation of landscapes (cf. Byoung-Eyang and Kaplan, 1990; Wherrett, 2000). However, this could also be a circular argument: seeing the high saliency and appreciation of seeing large water bodies, houses are usually built with a view overlooking these features if possible. This is highlighted by the high demand of homes having a view of the ocean or other water bodies which is reflected in the increased retail price of properties with a view over large water bodies (Bourassa et al., 2004; Jim and Chen, 2009).

Example 6.9
An overcast day, the tower blocks in the distance frame the olive green trees and parks in between. Two people are in the park doing fitness exercises on mats.

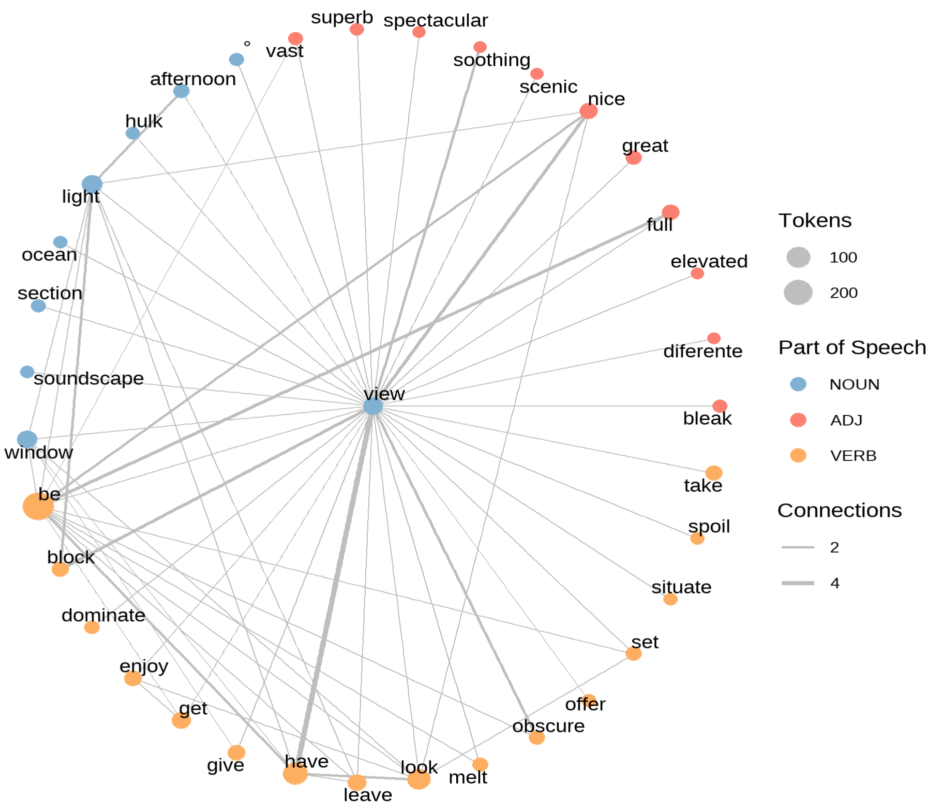


Figure 6.13: Subgraph of the lemma "*view*"

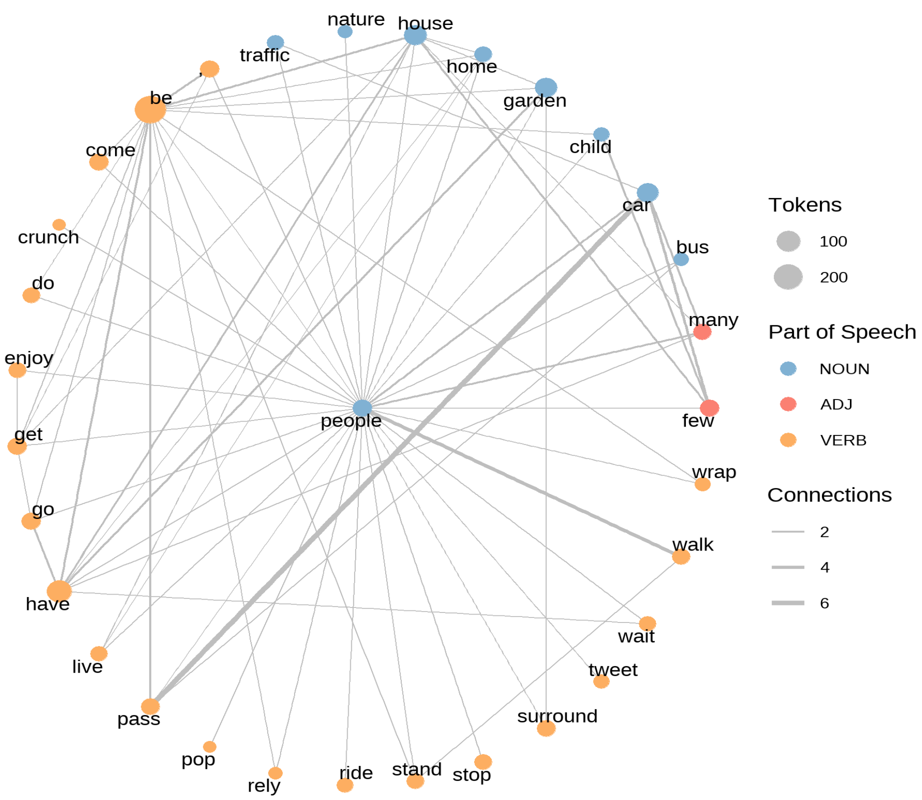


Figure 6.14: Subgraph of the lemma "*people*"

Finally, a graph was created from the term *"people"* (Figure 6.14) which is the most frequent term found significantly more often in $\mathbb{WE}^{en}$ than in $\mathbb{GEO}$ but not in $\mathbb{BNC}$. The term *"people"* is connected to a high number of verbs compared to nouns and adjectives. Connected verbs commonly signify what people are doing (e.g. *"come"*, *"crunch"*, *"go"*, *"live"*, *"pass"*, *"pop"*, *"ride"*, *"stand"*, *"stop"*, *"surround"*, *"tweet"*, *"wait"*, *"walk"* and *"wrap"*) whereas the only two connected adjectives refer to a relative number of people (e.g. *"many"*, *"few"*). These results suggest that when contributors perceive people in their everyday lived landscapes the activity they are performing becomes important as well as the number of people (cf. Example 6.9).

> Landscape features, temporal aspects and people are especially important in everyday lived landscapes. In addition, salient features (e.g. trees and buildings) are described using a large variety of composite terms to discriminate these from their surroundings.

6.5 Complementing computational analyses with human annotation

The findings of the presented analyses go to show how salient features of everyday lived landscapes can be extracted from natural language using computational methods. However, fully computational approaches reach their limits when exploring more intricate questions such as how landscapes are perceived through sensory experiences and what intangible dimensions are captured in the contributed descriptions, calling for human annotation. In the following I zoom in to the biophysical elements, sensory experiences and cultural ecosystem services captured within a subset of English descriptions, going beyond term frequencies to underlying semantics. A deeper inspection of the contributions through iterative annotation and exploring the linguistic context of salient terms can shed light on what people perceive as well as how and why certain features are perceived over others. Various frameworks exist geared towards enabling a better understanding of how cultural ecosystem services interact with other landscape elements, such as biophysical elements, and how these affect the perception of cultural ecosystem services (Fish et al., 2016). The combination of approaches from landscape perception research, geographic information science, linguistics and humanities allows for the exploration of how participants perceive cultural ecosystem services and how these are linked through sensory experiences to biophysical elements of a given landscape.

The following sections present the results of delving into the specifics of perceived biophysical elements in landscapes, individuals' sensory experiences in landscapes and the cultural ecosystem services that were implicitly or explicitly captured by the uploaded natural language landscape descriptions. To explore these dimensions, a subset of English *Window Expeditions* descriptions was annotated. The annotated subset[1] is very similar to the analysed English corpus presented above (cf. Section 6.4) and consists of 428 English contributions, uploaded between 16.08.2020 and 11.01.2022, by 325 users, from 45 unique regions or countries.

6.6 Biophysical elements in landscapes

In a first step of complementing the computational approaches of analysing natural language in regards to landscapes, biophysical landscape elements were identified and categorised. The biophysical elements of a landscape are the objects and tangible features that are found in an environment and are therefore important for landscape perception (Gibson, 1986; Dakin, 2003; Daniel et al., 2012; Fish et al., 2016). The most commonly found biophysical categories were *vegetation* (556 tokens of 18 unique lemmas in 248 descriptions), *built environment* (468 tokens of 17 unique lemmas in 217 contributions) and *weather / atmosphere* (452 tokens of 16 unique lemmas in 233 contributions). These were followed by *land cover* (306 tokens of 17 unique lemmas in 147 contributions), *building parts* (257 tokens of 12 unique lemmas in 147 contributions), *animals* (161 tokens of 12 unique lemmas in 103 contributions), *natural features* (124 tokens of 6 unique lemmas in 89 contributions) and *materials* (98 tokens of 10 unique lemmas in 79 contributions). Least common were the categories *people* (92 tokens of 5 unique lemmas in 72 contributions), *water* (67 tokens of 6 unique lemmas in 48 contributions) and *anthropogenic objects* (48 tokens of 8 unique lemmas in 36 contributions).

> **Example 6.10**
> The weather is very gloomy today, and it looks like it's going to rain. The trees are still leafless and the grass is not very green. The grass looks glossy because of the cold night temperatures and it looks like each piece of grass has water droplets on it.

These results point to two important considerations. Firstly, the most frequent categories *vegetation* and *built environment* correspond to the most frequently found landcover types and correspond to common categories in residential landscapes (cf. Zipperer et al., 1997; Schubarth and Weibel, 2013; Nielsen and Jensen, 2015) which is reflected in the importance of urban and natural dimensions in more general studies on landscape perception and landscape change (cf. Rapport et al., 1998; Domon and Bouchard, 2007; Fish et al., 2016; Fagerholm et al., 2020). This

[1] In the following the notation $\mathbb{WE}^{\text{en + annotated}}$ is used to refer to this corpus

suggests that the surrounding vegetation in combination with the configuration of the built environment are important in how individuals perceive their everyday lived landscapes. Weather related terms are also frequently encountered hinting at the importance of weather in how everyday lived environments are perceived (cf. Example 6.10), which has been suggested in the literature (cf. Gibson, 1986; Ingold, 2005). Even though the term "*ocean*" was frequently encountered with the term "*view*" as presented when comparing *Window Expeditions* contributions to other corpora (c.f. Section 6.4), water related lemmas belong to the least frequently found biophysical lemmas. This differs from findings of general landscape perception studies where water bodies are perceived as particularly salient landscape features (cf. Byoung-Eyang and Kaplan, 1990; Wherrett, 2000). This hints at either the biophysical category of *water* being less important in everyday lived landscapes compared to landscapes in general, or that water features are not present in the vicinity of many participants' homes.

Secondly, the results show differences in the number of tokens in relation to the number of unique lemmas and the number of contributions containing these terms. Noun lemmas referencing *vegetation* are frequently encountered ($n = 556$) and many unique lemmas were identified ($n = 18$), however, the number of contributions ($n = 248$) containing these lemmas is similar to that of the category *weather* ($n = 233$). Contributions containing terms categorised as *vegetation* commonly include multiple terms (e.g. *"tree"*, *"bush"*, *"flower"*, *"grass"* etc.) suggesting that contributors perceive various types of vegetation and the differentiation thereof is important in the perception and communication of their surroundings. The category of *weather* shows a considerably lower number of tokens found in a comparable number of contributions. This hints at weather related phenomena being more generally described in the English corpus (e.g. *"sun"*, *"fog"*, *"cloud"*) without the need for further specification (e.g. *"cumulonimbus clouds"*, *"valley fog"*, etc.).

After exploring what participants perceive and describe in terms of biophysical elements of everyday lived landscapes, the sensory experiences with which they perceive these elements become of interest.

> A wide variety of biophysical elements was found in everyday lived landscape descriptions contributed to *Window Expeditions*. The presence and type of perceived vegetation as well as the spatial configuration of the built environment and weather related phenomenon are particularly salient biophysical categories.

6.7 Sensory experiences in landscapes

Perceiving everyday lived landscapes is a multi-sensory process (Lynch, 1960; Tuan, 1975; Sepe, 2013). Therefore, in order to understand how our immediate environments are perceived, the sensory experiences of individuals in different landscapes must be investigated. In this thesis, a total of 248 $\mathbb{WE}^{\text{en + annotated}}$ contributions (57.9%) were identified as containing at least one dimension of the sensory experiences *sight*, *sound*, *smell/taste* and *touch/feel*. The majority of these were annotated as containing a single dimension ($n = 164$) followed by two ($n = 64$), three ($n = 18$) and all four ($n = 2$). Of these, *sight* was found to be the most commonly annotated dimension ($n = 186$), followed by *sound* ($n = 96$), *touch/feel* ($n = 61$) or *smell/taste* ($n = 11$). These results are in line with the literature showing *sight* as being most prominent in the perception of landscapes in Western languages with other sensory dimensions receiving less attention (cf. Zube et al., 1982; Kaymaz, 2012; Van Heijgen, 2014). The results also suggest the haptic dimension as an important contributor to how individuals perceive landscapes. This can be traced to weather related phenomena being important and many participants mentioning feeling the wind or commenting on the felt temperature (cf. Example 6.11).

> **Example 6.11**
> I feel a chill southerly wind I see the undulating trotternish ridge speckled with recent snow patches. Car noise occasionally. Some trees without leaves are seen. And there are mixed breeds of cows and their calves feeding in the field across the old drystone dyke. I se a hoodie crow and hear the cows hooves slurping through their slurry! Mairestails clouds above

Further, the contributions were annotated as being positive, negative or neutral sensory experiences. The results show positive experiences being most common ($n = 168$), followed by neutral ($n = 86$) and negative ($n = 68$) (Figure 6.15). This overrepresentation of positive experiences can, in part, be attributed to a positive bias in natural languages (cf. Dodds et al., 2015) or in landscape perception data as stated by experts (cf. Koblet and Purves, 2020). A subset of the contributions was found to contain multiple dimensions of sensory experiences ($n = 84$) with most frequently co-occurring dimensions being sight and sound ($n = 37$), followed by sight and feel ($n = 17$) and sight, sound and feel ($n = 14$) (Figure 6.15). These results indicate an overlap of visual and auditory perception of landscapes which is expected seeing they are the most common categories.

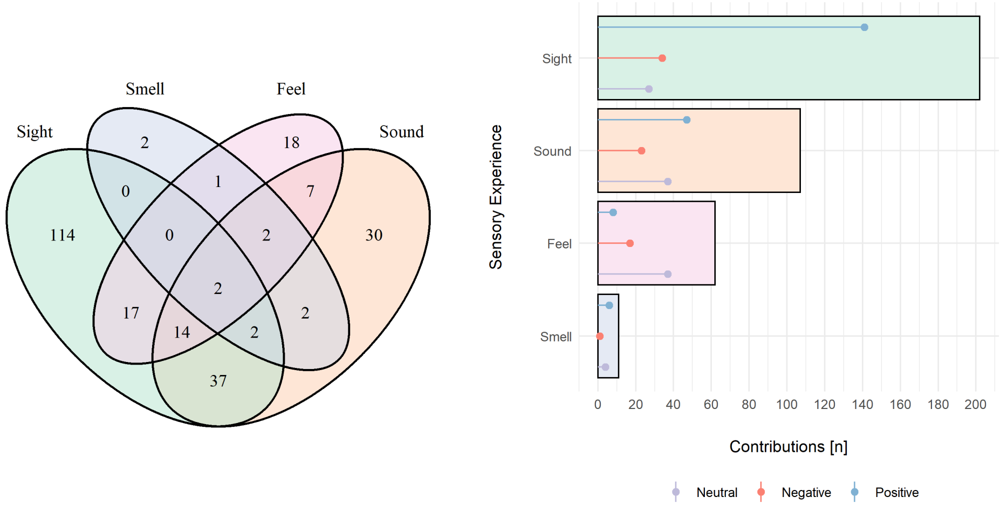


Figure 6.15: Statistics on sensory experiences. Left: Venn diagram showing the overlaps between annotated sensory experiences; Right: Distribution of annotated sensory experiences and respective attitudes

To further investigate sensory experiences within the $\mathbb{WE}^{\text{en + annotated}}$ corpus of landscape descriptions collected with *Window Expeditions*, terms occurring significantly ($p < 0.01$) more frequently within a given dimension compared to the whole corpus were identified by calculating each term's χ^2 value (cf. Chapter 5). The results show the noun lemmas *"bird"* ($n = 47$), *"sound"* ($n = 14$) and *"noise"* ($n = 12$), as well as the adjective lemma *"quite"* ($n = 31$) and the verb lemma *"hear"* ($n = 46$) to be significantly more frequent within descriptions annotated as containing the sensory experience of sound compared to the whole corpus. The significant over-representation of the lemma *"bird"* implies that participants commonly perceived birds through auditory perception. The remaining mentioned terms are closely related to the sensory experience of *"sound"* and either describe the act of perceiving (e.g. *"hear"*) or the presence or absence of auditory stimuli (e.g. *"noise"*, *"sound"*, *"quite"*). The results also show the term lemmas *"cold"* ($n = 25$) and *"wind"* ($n = 18$) being significantly more frequent in contributions annotated as containing the sensory experience of *touch/feel*. This suggests that many haptic experiences refer to weather related phenomena, especially the presence of wind and the feeling of cold.

To further explore the context of the most frequent significantly over-represented terms in the experiential sensory dimensions of *sound* and *touch/feel* (*"bird"* and *"cold"*) I extracted and plotted subgraphs of the immediate noun, verb and adjective dependencies (Figure 6.16 & 6.17). The results show the lemma *"bird"* being connected to a high number of other nouns, adjectives and verbs. However, the subgraph shows only three specifications of the type of bird (*"pigeon"*, *"robin"*, *"wren"*) showing two or more syntactic connections to the lemma "*bird*".

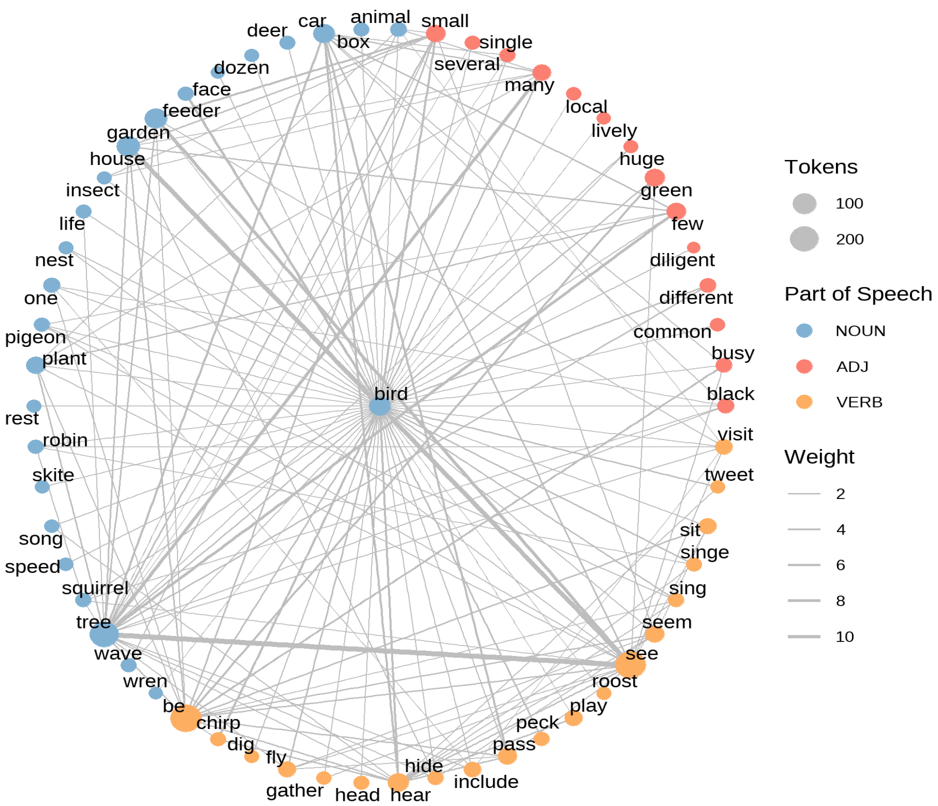


Figure 6.16: Subgraph of the lemma "*bird*"

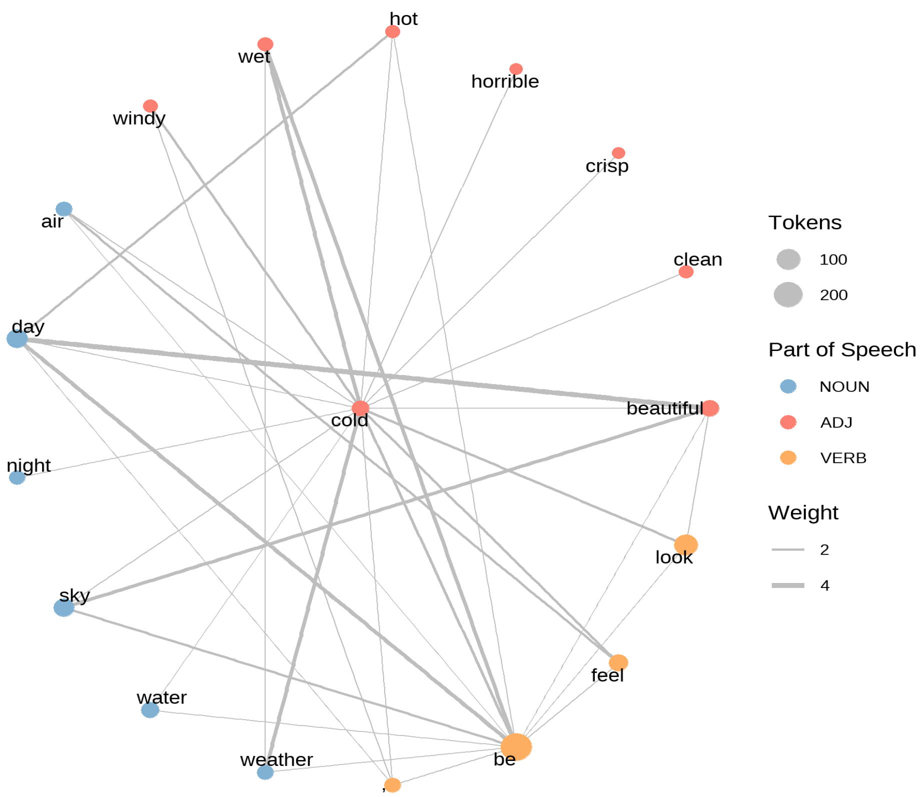


Figure 6.17: Subgraph of the lemma "*cold*"

This is in stark contrast with the syntactic neighbourhood graph of the lemma *"tree"* which lists a large number of types of trees (cf. Figure 6.11). When further exploring the subgraph of the lemma *"bird"*, the results show many adjectives related to quantity and size (e.g. *"small"*, *"single"*, *"several"*, *"many"*, *"huge"*, *"few"*) as well as many bird-related verbs (e.g. *"roost"*, *"peck"*, *"fly"*) including those related to sound (e.g. *"tweet"*, *"sing"*, *"chirp"*). The nodes and relations found in the subgraph of the term "cold" (Figure 6.17) paint a different picture. This subgraph shows considerably less connections overall, indicating less diversity in descriptions containing the term *"cold"*. Connections can be found between the adjective *"cold"* the verb *"feel"* and the noun *"air"*, pointing towards the haptic perception of cold air which is categorised as weather related phenomena. This is underlined by a number of additional weather or atmospheric related terms connected to the term *"cold"* (e.g. *"weather"*, *"sky"*, *"windy"*, *"wet"*, *"hot"*, *"crisp"*). Finally, the term "*cold*" is connected to the nouns *"day"* as well as *"night"*, indicating the importance of the term as a general temporal attribute of a landscape.

Example 6.12
It's a grey day today, but just in the last day or so everything has started to transition from spring green into summer. Buttercups have sprung up in the strip left between our back fence, and the one (a road's-width away) that delineates the recycling centre's boundaries. My birdfeeder is now a popular socialising spot for the locals, so there's a regular stream of blackbirds, blue tits, great tits, starlings (about 15 of them), goldfinches, the occasional chaffinch – and the magpies. The magpie is currently engaged in an aggressive battle against the suet feeder. It's a weird combination, this view, of this kind of British garden wildlife, and the looming hulk of the recycling centre behind. It always feels to me like a constant threat: like this grey and desolate surface will be everywhere if you don't keep a careful eye on it.

Contrary to what one would expect after exploring the subgraph of the term "*bird*" presented above, the annotators encountered a large variety of bird types during the iterative annotation process of the contributions (cf. Example 6.12). To investigate this discrepancy between the high number of specific bird types mentioned in contributions and the lack thereof in the subgraph of the lemma *"bird"* (Figure 6.16), a list of English names for known bird species was imported and compared to the contributions to *Window Expeditions*. A total of 50 unique bird species mentioned in 47 contributions were found ranging from green parakeet and blue jay to acorn woodpecker and house martin. The most commonly mentioned species was found to be *"magpie"* ($n = 7$), followed by *"robin"* ($n = 6$), *"blackbird"* ($n = 5$), *"chicken"* ($n = 5$) and *"pigeon"* ($n = 5$). These results highlight the variety of birds perceived in everyday lived landscapes as well as contributors preferring to refer to individual species of birds rather than the higher level category of *"bird"*. Noteworthy is the varying level of detail within the category of bird species where the bird species of *"tit"* was found most often ($n = 9$), however, participants commonly referred to the specific type of tit (e.g. *"great tit"*, *"coal tit"*, *"blue tit"*, *"long-tailed tit"*). This goes to show that even within a specific category of features important in perceiving everyday lived landscapes, the level of detail in which participants describe elements varies greatly. This calls for further consideration of basic levels as well as subordinate and superordinate categories (cf. Tversky and Hemenway, 1983; Hajibayova, 2013).

> Apart from the commonly investigated visual dimension, the auditory and haptic dimensions are important in perceiving everyday lived landscapes. The sounds of birds and the feeling of weather related phenomena are particularly important sensory experiences.

6.8 Cultural ecosystem services in landscapes

In addition to biophysical elements and sensory experiences, landscapes are also accompanied by various intangible dimensions and affordances. These can shed light on the deeper meanings of landscapes and how landscapes are interacted with. The contributions were thus further explored with a particular focus on cultural ecosystem services.

Just over one third ($n = 132$) of the collected $\mathbb{WE}^{\text{en + annotated}}$ descriptions were annotated as referring to at least one cultural ecosystem service. The majority of these contributions were annotated as containing a single cultural ecosystem service ($n = 100$), followed by two ($n = 26$) and three ($n = 6$). The most frequently annotated cultural ecosystem service was *recreation* ($n = 68$) followed by *heritage* ($n = 36$), *identity* ($n = 26$) and *tranquillity* ($n = 23$) (Figure 6.18). Least common were *inspiration* ($n = 12$) and *religious values* ($n = 5$). A number of contributions ($n = 32$) were annotated as containing references to more than one cultural ecosystem service. Most common overlaps were found between *recreation* and *heritage* ($n = 6$), *heritage* and *identity* ($n = 5$) as well as *recreation* and *tranquillity* ($n = 5$) (Figure 6.18).

The results point towards recreational affordances being a salient dimension of perceiving landscapes which is in line with the literature (cf. Bieling, 2014; Wartmann and Purves, 2018; Fagerholm et al., 2020; Wartmann et al., 2021a). *Heritage* was found to be annotated frequently indicating the dimension's importance for everyday lived landscapes, albeit less frequently found in perception studies of landscapes in general (Bieling, 2014; Fagerholm et al., 2020). The overlaps between *recreation* and *tranquillity* suggest a connection between places of recreation and places of tranquillity. Further, the overlaps between *heritage* and *identity* point towards participants mentioning a feeling of belonging or recalling memories within a landscape when describing the perceived landscape elements in terms of their cultural significance.

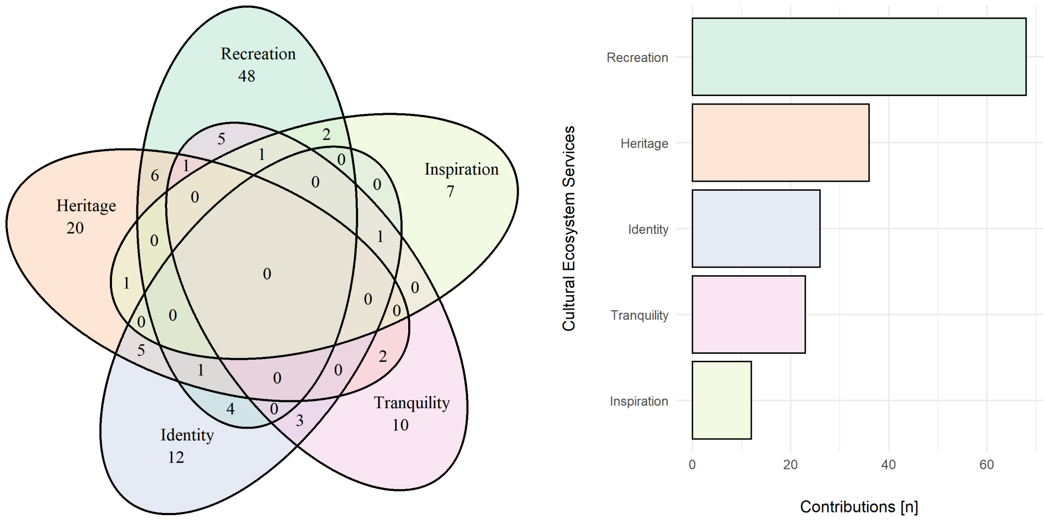


Figure 6.18: Statistics on cultural ecosystem services. Left: Venn diagram showing the overlaps between annotated cultural ecosystem services; Right: Distribution of annotated cultural ecosystem services

Through a χ^2 analysis (cf. Chapter 5), term lemmas found significantly ($p < 0.01$) more often within contributions annotated as belonging to a specific cultural ecosystem service compared to the whole $\mathbb{WE}^{\text{en + annotated}}$ corpus were identified. The results show *heritage*, *recreation* and *religious values* to contain such terms with *"old"* ($n = 22$) found significantly more frequently within *heritage*, *"park"* ($n = 14$) within *recreation* and *"see"* ($n = 12$) within *religious values*. For the identified terms *"old"*, *"park"* and *"see"*, the respective subgraphs of connected nouns, adjectives and verbs were extracted and explored.

Example 6.13
I am sitting outside the chalet. I can see the forests around us and the mountain tops of the valley, many of which are covered in snow and clouds now because of the unusually cold and wet weather. There is an old valais hut (grange) in the meadow in front of the chalet. The meadow is mostly green as the flowers only awake once the sun comes out. I hear the birds and some cars in the distance. There is a cool breeze of fresh mountain air but because of the clouds, the sky is grey.

Firstly, the subgraph of the lemma *"old"* (Figure 6.19) shows a large number of connections with predominantly nouns, especially nouns associated with anthropogenic infrastructure (cf. Example 6.13). This includes references to specific anthropogenic structures potentially of higher cultural relevance such as *"castle"*, *"church"*, *"dyke"*, *"mill"* and *"quarry"* which is in line with the literature (cf. Swetnam et al., 2017;

Baumeister et al., 2020), as well as more generic terms such as *“bridge”*, *“building”*, *“campus”*, *“harbour”*, *“house”*, and *“town”*.

Secondly, the subgraph showing the context of the term *“park”* (Figure 6.20) on the other hand includes a more diverse collection of nouns, adjectives and verbs. The nouns include elements that can be found in parks (e.g. *“wood”*, *“tree”*, *“pond”*, *“gate”*) as well as terms related to green spaces more generally (e.g. *“greenspace”*, *“garden”*). The adjectives mostly refer to size (e.g. *“small”*, *“sized”*, *“large”*) or describe the vegetation (e.g. *“natural”*, *“lush”*, *“green”*, *“golden”*). Finally, the verbs are more generic and seem to be less related to parks but more to recreational areas in general (cf. Example 6.9). The importance of parks in the perception of everyday lived landscapes is reflected in the literature showing the beneficial effects of (urban) greenspaces on well-being and being important recreational areas (Stålhammar and Pedersen, 2017; Wood et al., 2018; Vujcic et al., 2019; Baumeister et al., 2020).

Finally, the subgraph of the context of the term "*see*" shows only one identified syntactic relationship to the term "*through*" and was thus not plotted. This indicates that the term "*see*" is commonly mentioned as a means of describing the active perceptual experience of looking *through* a window or otherwise transparent surface. Thus, the term "*see*" being significantly overrepresented in contributions annotated as referring to the cultural ecosystem services of *religious values* can be seen as a result of the small number of contributions annotated as containing references to *religious values*.

> "*Recreation*" and "*heritage*" are particularly salient intangible dimensions of everyday lived landscapes with parks being important in the former and old structures in the latter.

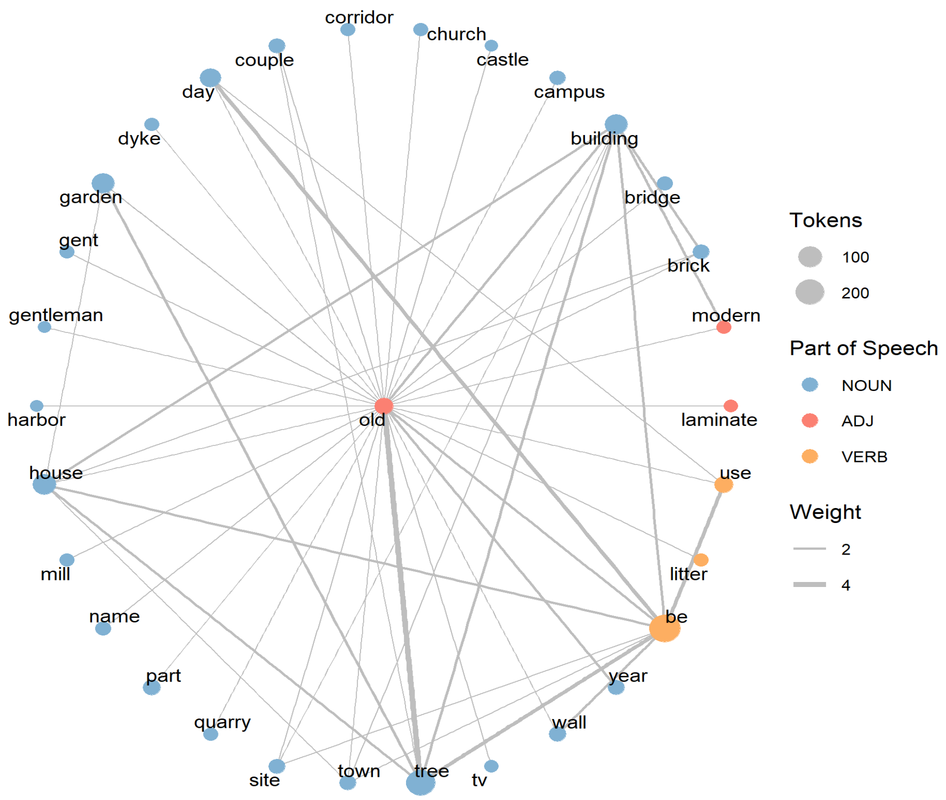


Figure 6.19: Subgraph showing the immediate neighourhood of the term "*old*"

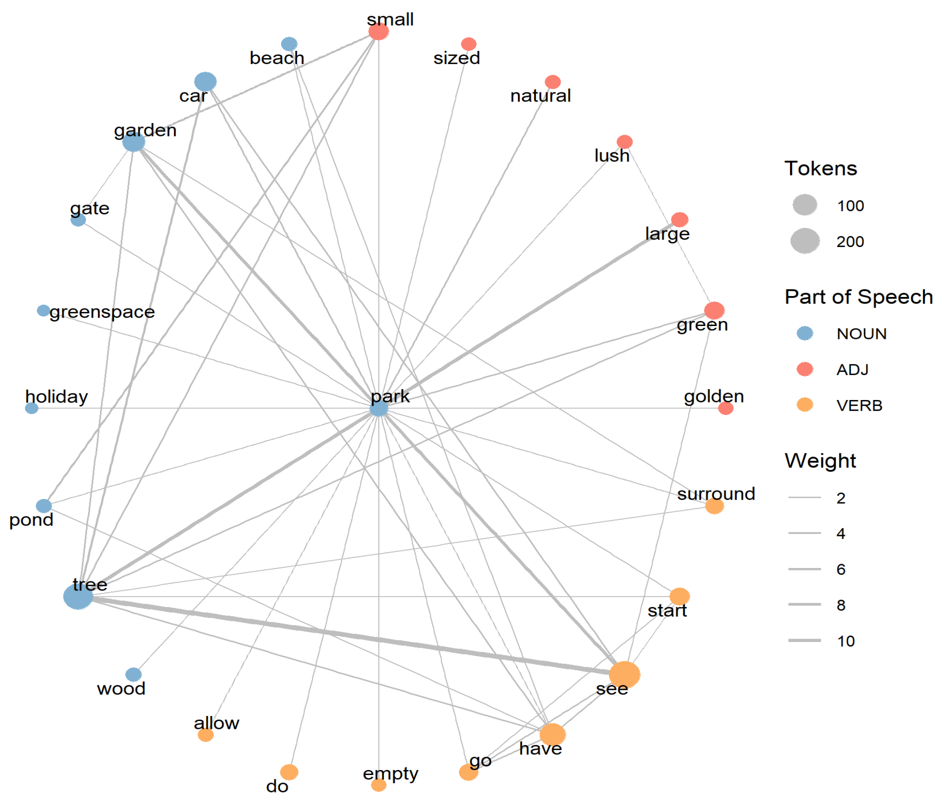


Figure 6.20: Subgraph showing the immediate neighourhood of the term "*park*"

6.9 Linking biophysical elements, sensory experiences and cultural ecosystem services

After looking into the individual dimensions of biophysical elements, sensory experiences and cultural ecosystem services, questions of how these relate to each other become important. In order to investigate how contributions annotated as referring to sensory experiences and cultural ecosystem services are associated with annotated biophysical elements, co-occurring elements and dimensions were extracted and differences were investigated using χ^2 testing (Figure 6.21). The results show no significant ($p = 0.02$) differences within the distribution of biophysical categories and sensory experiences. When exploring the residuals of the χ^2 statistics, the biophysical category of *animals* is found to be less associated with the sensory dimension of *sight* and more with *smell*. This suggests that contributions mentioning animals were particularly prone to mention smell or taste of the environment, however not necessarily related to the mentioned animals. Further, the results show the sensory experience of *sound* being more associated with the biophysical category of *moving objects*. Participants frequently mentioned hearing various motorised modes of transport such as cars or trains.

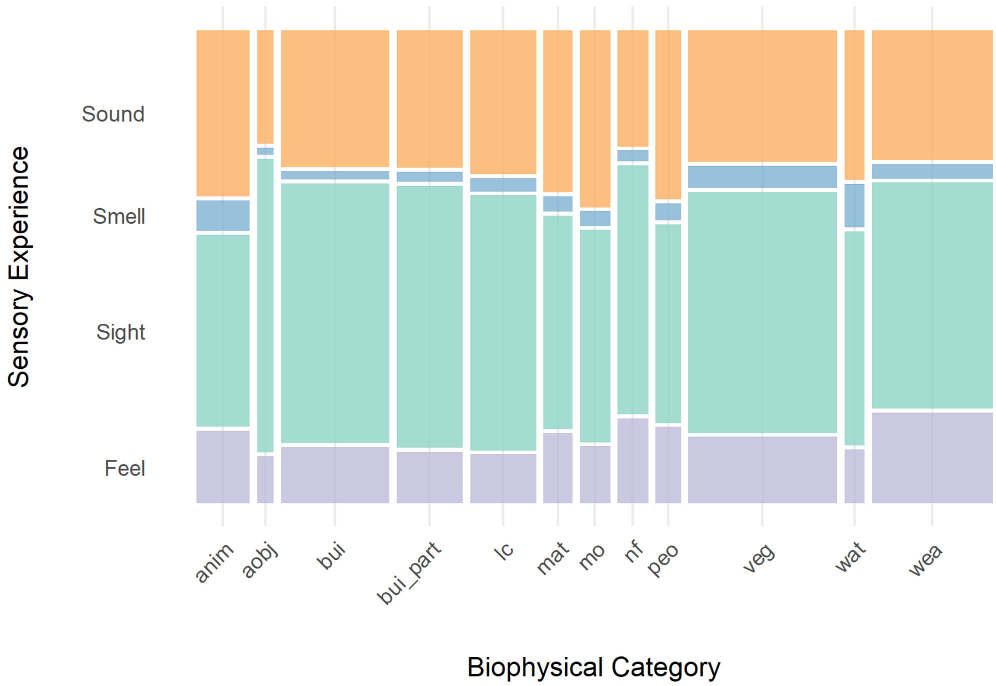


Figure 6.21: Mosaic diagram showing the distribution and count of annotated biophysical categories for each annotated sensory experience. **Categories:** *animals (anim), anthropogenic objects (aobj), built environment (bui), building parts (bui_part), land cover (lc), materials (mat), moving objects (mo), natural features (nf), people (peo), vegetation (veg), water (wat), weather / atmosphere (wea)*

The same procedure was used to explore the relations between biophysical elements and cultural ecosystem services (Figure 6.22). The results of the χ^2 analysis shows no significant ($p = 0.14$) differences in the distributions. However, when inspecting the residuals, three noteworthy outliers were found. The cultural ecosystem service *religious values* is highly associated with the biophysical element *built environment*, *inspiration* with *natural features* and *tranquillity* with *weather*.

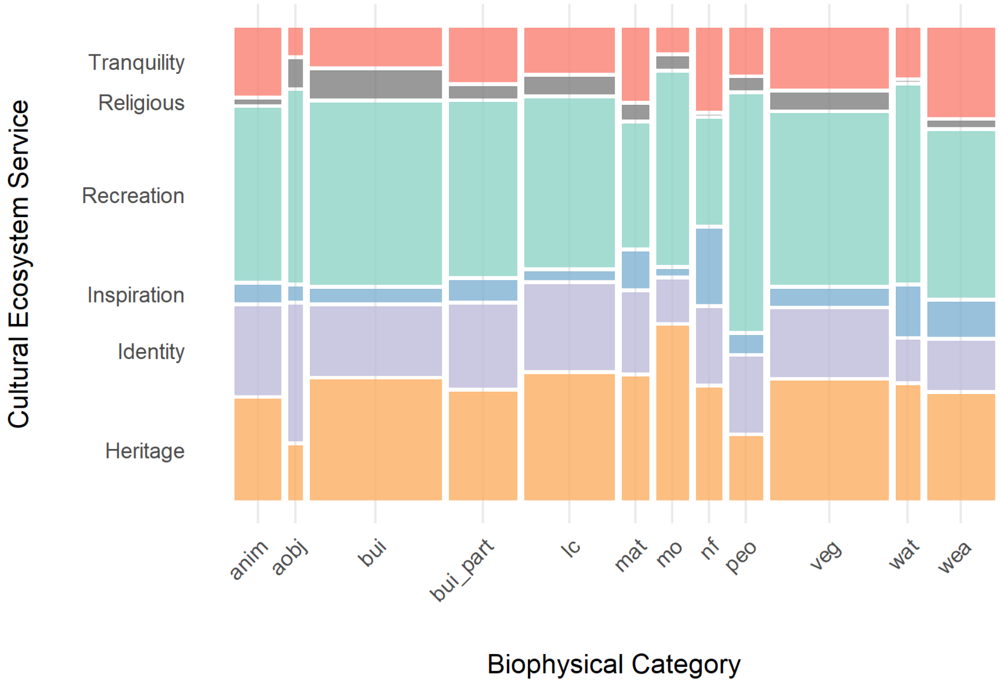


Figure 6.22: Mosaic diagram showing the distribution and count of annotated biophysical categories for each annotated cultural ecosystem service. **Categories:** *animals (anim), anthropogenic objects (aobj), built environment (bui), building parts (bui_part), land cover (lc), materials (mat), moving objects (mo), natural features (nf), people (peo), vegetation (veg), water (wat), weather / atmosphere (wea)*

To tie together sensory experiences and cultural ecosystem services, co-occurrences in $\mathbb{WE}^{\text{en + annotated}}$ were explored. Four stacked bar plots were created for each of the dimensions of sensory experiences showing the number of co-occurring cultural ecosystem services. The plots (Figure 6.23) show most co-occurrences being found between the sensory experiences of *sight* and *sound*. The most frequent cultural ecosystem service *recreation* is highly correlated with both *sight* and *sound*, which is in part a result of the high frequency of these sensory experiences as well as the cultural ecosystem service. The graphs show that most cultural ecosystem services co-occur with positive visual sensory experiences. However, comparing annotated cultural ecosystem services with the auditory dimension shows a more balanced distribution of positive, negative and neutral sensory experiences. Cultural ecosystem services co-occurring with references to the haptic dimension show no solely positive experiences and co-occurrences with the olfactory dimension show no negative experiences. The results point to two important considerations. Firstly, as expected, visual and auditory experiences seem to be predominant in the perception of cultural ecosystem services. Secondly, the distribution of positive and negative sensory experiences seems to be dependent on the dimension of sensory experience and not on the perceived cultural ecosystem service. *Sight* was found to be predominantly positive, *sound* a balanced distribution, *feel* predominantly negative and *smell* only positive (cf. Example 6.14). However, more data would be needed to strengthen this argument.

Example 6.14

- I see a copper beech, now in full leaf, glorious pink blossom on a tree I don't know the name of, and fresh greenery wherever I look. There are a few very late daffodils across the road, and the sound of birdsong is everywhere.
- Many spruce trees with yellow birch speckled in between. Although I can hear the street, it looks like I am sitting in the middle of a wood. There's a large lime tree with yellow autumn foliage hovering on the right in the foreground.
- It's breezy. Gusts of only 3-4 but feels very chilly! I can see white horses on the grey waters of the Minch. A flock of gulls float above the cliffs. I hear Curlews call from the shore and the wind blowing. Meadow pipit calls. I can smell the silage a neighbouring crofter has just put out for the cattle!
- The trees have spanish moss on them, so it looks like a party is happening, and it smells like gardenias and jasmine. It's hot out, but it is really quiet and the ground is sandy.

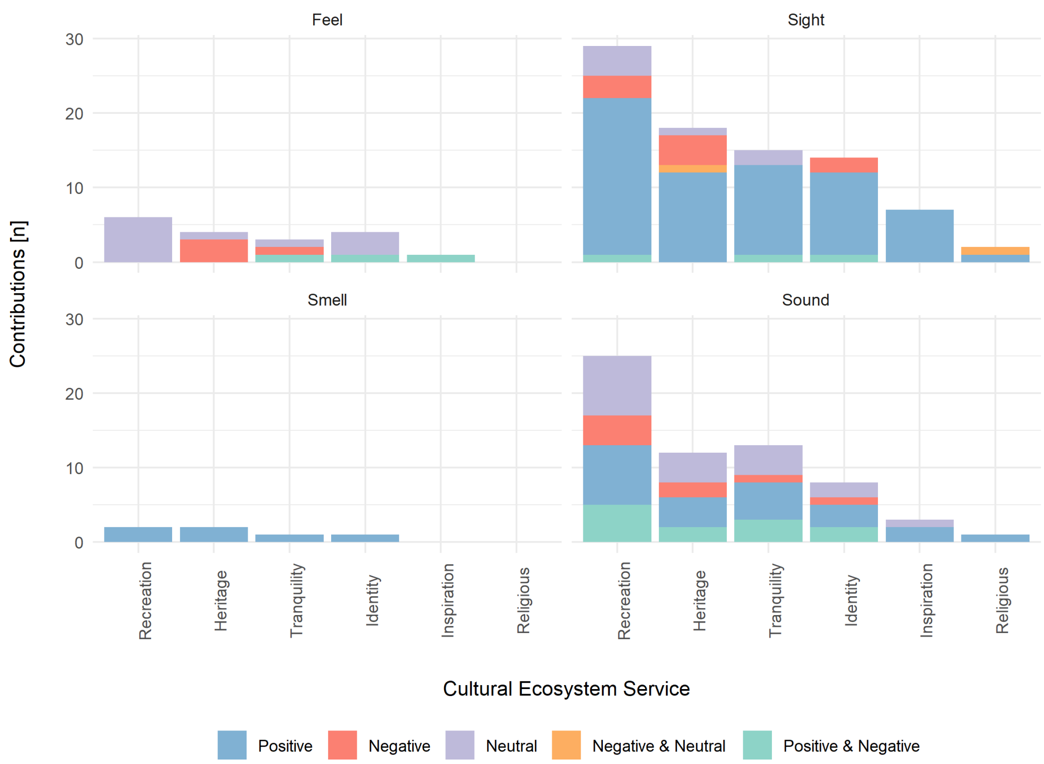


Figure 6.23: Bar plots showing the distribution of cultural ecosystem services within each sensory experience

To further explore co-occurring dimensions of sensory experiences and cultural ecosystem services a directed graph was produced where the nodes represent the dimensions of sensory experiences as well as cultural ecosystem services and the directed edges represent the frequency of one dimension co-occurring with another (Figure 6.24). The graph highlights connections between sensory experiences and cultural ecosystem services and shows *religious values* (66.7%) and *inspiration* (63.6%) co-occurring particularly frequently with *sight*. However, it must be noted that only 3 contributions annotated as referring to *religious values* were found to also contain references to sensory experiences. Further, the results show *tranquillity* (40.6%) and *recreation* (40.3%) co-occurring frequently with *sound*. Finally, the results show the cultural ecosystem service of *identity* (14.8%) co-occurring slightly more frequently with the haptic dimension compared to other cultural ecosystem services. The results suggest that firstly, moments of inspiration in landscapes seem to be triggered by visual cues, calling for further investigation of the inspirational visual character of landscapes. Secondly, perceiving the presence or absence of sounds is important in how we perceive recreational areas as well as tranquil areas in everyday lived landscapes, which is in line with more general landscape research (cf. Koblet and Purves, 2020; Wartmann et al., 2021a; Wartmann et al., 2021b).

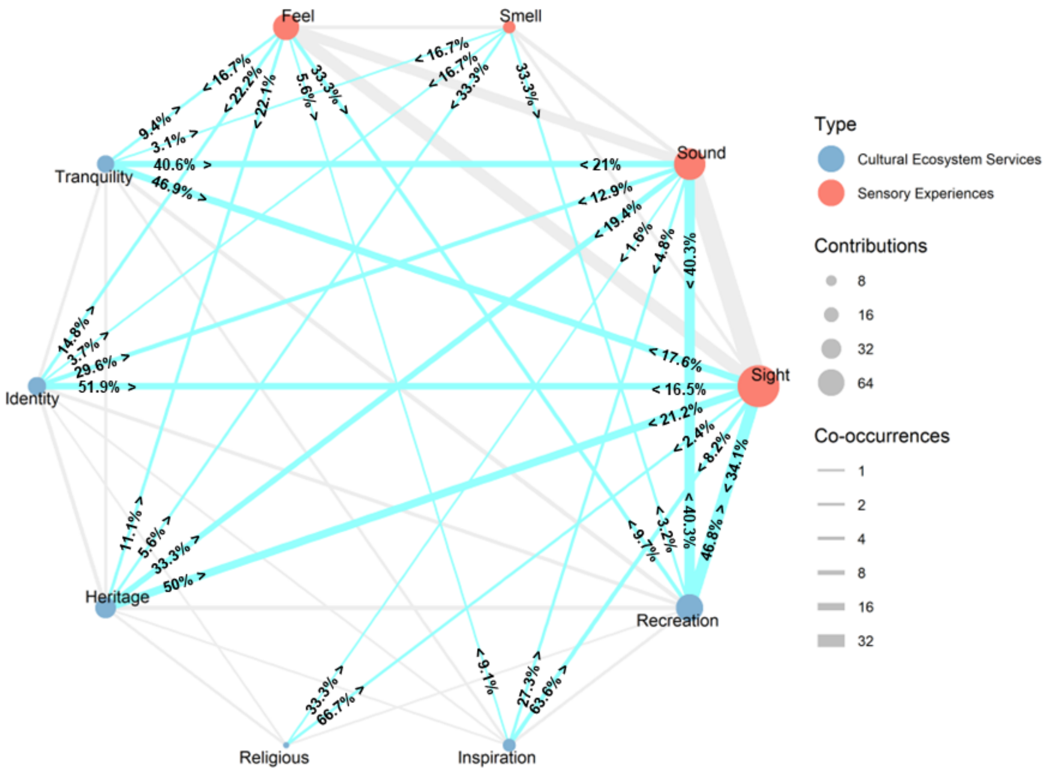


Figure 6.24: Graph of co-occurring sensory experiences and cultural ecosystem services. The edge labels show the percentage of documents from one dimension co-occurring with another dimension

Lastly, the cultural ecosystem service of *identity* seems to be related to the haptic experience of a landscape, potentially pointing towards weather or wind related phenomena (as the main annotated categories of the haptic dimension) being important for identity.

> The contributions to *Window Expeditions* show *animals* being associated with olfactory experiences, *moving objects* with auditory experiences, *natural elements* with *inspiration* and *weather* with *tranquility*. Visual sensory experiences were found to have a positive connotation whereas the auditory dimension was more balanced between positive, negative and neutral connotations. The haptic dimension showed no solely positive experiences whereas the olfactory dimension was solely positive.

6.10 Diversity and domain specificity of *Window Expeditions*

Adding human annotations to complement computational methods is common in landscape perception research (cf. Wartmann and Purves, 2018; Fagerholm et al., 2020). A subset of English contributions was annotated and particular focus was put on biophysical elements, sensory experiences and cultural ecosystem services as well as combinations thereof. The results presented above go to show the diversity and domain specificity of the captured categories, dimensions and experiences in the *Window Expeditions* corpus. The corpus includes biophysical elements, positive and negative sensory experiences and a wide array of cultural ecosystem services, however, the number of contributions remains rather small. To explore if the presented results remain stable, a larger dataset of landscape relevant natural language descriptions of everyday lived landscapes is needed. In the following chapter, natural language processing and sentence-transformer workflows are combined to extend the original corpus. Using a rich annotated natural language corpus to identify similar documents in other datasets opens the door to large scale analyses and more robust interpretations.

7 Generating Large Landscape Relevant Corpora

> *Words can be like X-rays if you use them properly – they'll go through anything. You read and you're pierced.*
>
> — **Aldous Huxley**
>
> (Author)

The previous chapter has shown that the corpus generated through *Window Expeditions* is rich in landscape relevant information and high in quality. However, the generated corpus is rather small, limiting large-scale explorations of landscape perceptions. Therefore, the question arises: how can the generated corpus be used to generate a large domain specific corpus? Natural language processing and computational linguistics have been applied to generate landscape relevant natural language corpora, for example through automatic extraction of geographic information from scientific articles (Acheson and Purves, 2021) or a rule-based approach of extracting relevant information from online text sources (Koblet and Purves, 2020). However, many efforts in building domain specific corpora start without a preexisting gold standard dataset to inform the corpora building process. In this chapter I explore the potential of translating natural language to vectors to identify similar domain specific documents. Specifically, this chapter investigates the potential of using a high quality and domain specific actively crowdsourced corpus of everyday lived landscape descriptions to identify landscape relevant documents in other corpora.

The English *Window Expeditions* corpus ($\mathbb{WE}^{en}$) used in the previous chapter (cf. Chapter 6), consisting of 428 contributions, was converted to vectors using sentence-transformers (cf. Chapter 5). In addition, a subcorpus[1] of 410 contributions was created that contained at least one Craik's list adjective or biophysical noun (identified and annotated in (Chapter 6)) found significantly more frequently in *Window Expeditions* than in general English natural language ($\mathbb{BNC}$). I compared the *Window Expeditions* corpus to two other corpora: one from the same domain (*Geograph* (Chesnokova and Purves, 2018)) and one from a different domain (*WikiHow* (Koupaee and Wang, 2018)), with the expectation that similarity values from texts of the same

[1] In the following the notation $\mathbb{WE}^{craik/bio}$ is used to refer to this corpus

domain would be higher. A corpus of 4562613 non-empty *Geograph*[2] image descriptions as well as a subcorpus[3] of 2239670 image descriptions containing at least one Craik's list adjective or biophysical noun (found significantly more frequently in *Window Expeditions* than in general English ($\mathbb{BNC}$)) were converted to vectors. Cosine similarity scores were calculated between all $\mathbb{WE}$ and $\mathbb{GEO}$ vectors as well as between all $\mathbb{WE}^{\text{craik/bio}}$ and $\mathbb{GEO}^{\text{craik/bio}}$ vectors. In addition, a corpus of 1585695 *WikiHow* (cf. Koupaee and Wang, 2018) contributions[4] were translated to vectors and cosine similarity scores between $\mathbb{WE}$ and $\mathbb{WIKI}$ were calculated.

7.1 Craik's list adjectives and biophysical nouns

The results show that by only including contributions and comments that contained at least one Craik's list adjective or biophysical noun the number of documents in *Window Expeditions* was reduced by 4.2% ($\mathbb{WE} - \mathbb{WE}^{\text{craik/bio}} = 18$) eliminating a small number of contributions with no landscape relevance. The number of documents in *Geograph* was reduced by 50.9% ($\mathbb{GEO} - \mathbb{GEO}^{\text{craik/bio}} = 2322943$), effectively halving the number of documents whilst increasing the potential of the document to be similar to *Window Expeditions*. Filtering documents before translating these to multidimensional vectors results in faster processing times as well as a shift towards higher similarity scores whilst remaining highly scalable due to being easily parallelised. This goes to show the domain and genre specificity of contributions to *Window Expeditions* as well as the potential of using signifier terms to detect potentially similar documents in another corpora.

Both $\mathbb{WE}$ and $\mathbb{GEO}$ as well as $\mathbb{WE}^{\text{craik/bio}}$ and $\mathbb{GEO}^{\text{craik/bio}}$ were translated to a multidimensional vector space and the cosine similarity scores between $\mathbb{WE}$ and $\mathbb{GEO}$ as well as between $\mathbb{WE}^{\text{craik/bio}}$ and $\mathbb{GEO}^{\text{craik/bio}}$ were calculated. The results show a small significant (two-sample Kolmogorov-Smirnov test: $p = 0.05$; Welch two sample t-test: $p < 0.01$) difference in the distribution of similarity scores with $\mathbb{WE}$ and $\mathbb{GEO}$ showing lower similarity scores ($mean = 0.1936$, $variance = 0.0119$) compared to using the datasets filtered by Craik's list adjectives and biophysical nouns ($\mathbb{WE}^{\text{craik/bio}}$ and $\mathbb{GEO}^{\text{craik/bio}}$; $mean = 0.2009$, $variance = 0.0118$) (cf. Figure 7.1). The means and variances were calculated using Welford's online algorithm (Ling, 1974; Chan et al., 1983) as the size of the dataset was too large to store in memory.

[2] In the following the notation $\mathbb{GEO}$ is used to refer to this corpus
[3] In the following the notation $\mathbb{GEO}^{\text{craik/bio}}$ is used to refer to this corpus
[4] In the following the notation $\mathbb{WIKI}$ is used to refer to this corpus

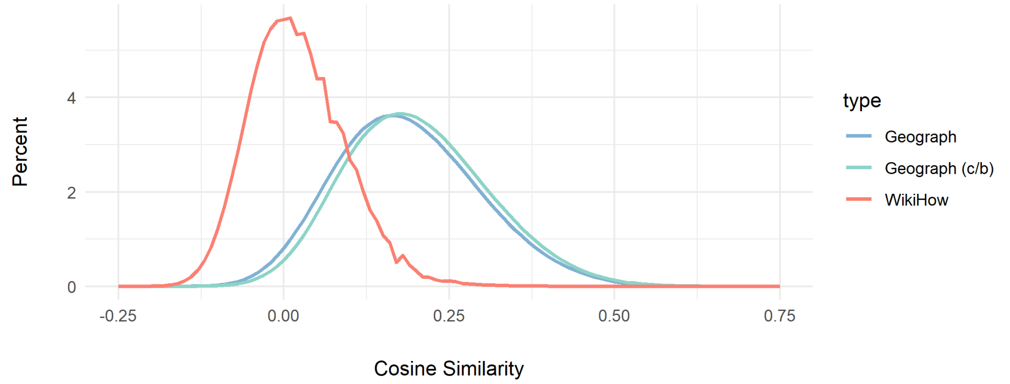


Figure 7.1: Cosine similarity score distributions when comparing $\mathbb{WE}$ to $\mathbb{GEO}$, $\mathbb{WE}^{craik/bio}$ to $\mathbb{GEO}^{craik/bio}$ and $\mathbb{WE}$ to $\mathbb{WIKI}$. (C/B): dataset prefiltered using Craik's list and biophysical terms

These small but significant differences in similarity scores, combined with the large reduction in processed documents due to prefiltering, suggest that a slightly higher percentage of similar documents can be found when comparing cosine similarity scores between the prefiltered corpora ($\mathbb{WE}^{craik/bio}$ and $\mathbb{GEO}^{craik/bio}$) as opposed to the whole corpora ($\mathbb{WE}$ and $\mathbb{GEO}$). In addition, using signifier terms greatly reduces processing time since many irrelevant documents are discarded before translating into multidimensional vector space using sentence-transformers. However, these results must be taken with a grain of salt: the higher similarity scores could be a function of at least one signifier term being present in all documents of both corpora. In other words, every $\mathbb{GEO}^{craik/bio}$ image description contains at least one term that can be found in at least one $\mathbb{WE}^{craik/bio}$ contribution.

To further investigate the chosen approach of translating texts to vectors and using cosine similarity scores to identify similar documents, $\mathbb{WE}$ was compared to $\mathbb{WIKI}$, a natural language corpus from a different domain. The results show cosine similarity scores between $\mathbb{WE}$ and $\mathbb{WIKI}$ to be significantly (two-sample Kolmogorov-Smirnov test: $p = 0.09$; Welch two sample t-test: $p < 0.01$) lower ($mean = 0.02639$, $variance = 0.0052$) than the cosine similarity scores between $\mathbb{WE}$ and $\mathbb{GEO}$ presented above. Investigating the distribution of cosine similarity scores reveals most values to be very low with a peak around 0. This suggests that cosine similarity score distributions tell us something about domain specificity with distributions around 0 indicating low landscape relevance. In addition, this underlines the higher similarity of *Window Expeditions* and *Geograph* contributions due to their shared domain specificity and highlights that multidimensional vector representations of texts are capable of capturing a text's underlying semantics. As such, a high cosine similarity score indicates high semantic similarity between documents, whereas a low cosine similarity score suggests documents do not contain landscape relevant information.

To explore similar documents in more detail, documents with a cosine similarity of 0.7 or above were extracted for $\mathbb{GEO}$ and $\mathbb{WE}$ as well as for $\mathbb{GEO}^{\text{craik/bio}}$ and $\mathbb{WE}^{\text{craik/bio}}$. This threshold was identified as being a suitable trade-off between similarity and number of documents. The results show 243 *Window Expeditions* contributions (56.8%) to have at least one similar *Geograph* image description when using the whole corpora and 225 contributions (54.9%) when only using contributions containing at least one Craik's list adjective or biophysical noun. Further, 8172 *Geograph* image descriptions (0.18%) were found with a cosine similarity score above 0.7 using the whole dataset and 6075 (0.27%) when using the prefiltered dataset. To avoid confusion the corpus of *Window Expeditions* contributions identified as being similar to at least one *Geograph* image description is referred to as $\mathbb{WE}^{\text{sim}}_{\text{geo}}$ and the corpus of *Geograph* image descriptions identified as being similar to at least one *Window Expeditions* contribution is referred to as the $\mathbb{GEO}^{\text{sim}}_{\text{we}}$ in the remainder of this chapter. When referring to the corpora prefiltered with Craik's list adjectives and biophysical nouns, the corpora are referred to as $\mathbb{WE}^{\text{sim + craik/bio}}_{\text{geo}}$ and $\mathbb{GEO}^{\text{sim + craik/bio}}_{\text{we}}$ respectively.

Example 7.1

- When it come to autumn colour, beeches are the most colourful of our native species, retaining their leaves longer than most other species, and displaying a range of vivid gold, orange and russet until well into November. (cosine similarity = 0.85) (By Anne Burgess[a])
- Snow, which I believe fell for about 15 hours the previous day and night, has been removed from the tops of the trees by strong winds, but it has adhered to the eastern side of trunks and branches, and lies thick on the ground. It's been excellently scrunchy snow for snowmen and snowballs. This view is from where [5715067] was taken. (cosine similarity = 0.84) (By Derek Harper[b])
- Beautiful sand, interesting surf, good rocky outcrops make this an excellent beach. With little wind there is still surf, with some westerlies this beach gets exciting. (cosine similarity = 0.83) (By Peter Church[c])

[a] www.geograph.org.uk/photo/5198765 (accessed: 11.06.2022)
[b] www.geograph.org.uk/photo/5715187 (accessed: 11.06.2022)
[c] www.geograph.org.uk/photo/2618094 (accessed: 11.06.2022)

A first visual inspection of the *Geograph* image descriptions identified as being similar to at least one *Window Expeditions* contribution shows highly similar texts were identified containing rich landscape relevant data (cf. Example 7.1), hinting at the potential of the proposed workflow. The characteristics of $\mathbb{GEO}^{\text{sim + craik/bio}}_{\text{we}}$ were further investigated through natural language processing and latent Dirichlet allocation topic modelling, to strengthen the argument that small high quality corpora can be used to automatically identify similar documents in other collections.

To further investigate the effect of using signifier terms to prefilter the corpora before processing, the frequency of individual noun, adjective and verb lemmas of the resulting corpora were compared. The Jaccard similarity score, as a measure of overlap between noun, adjective and verb lemmas found in the unfiltered $\mathbb{GEO}^{\text{sim}}_{\text{we}}$ and the prefiltered $\mathbb{GEO}^{\text{sim + craik/bio}}_{\text{we}}$ corpora, shows an almost complete overlap (Jaccard similarity: 0.9416). This suggests that prefiltering leads to similar results regarding the distribution of parts of speech (e.g. nouns, adjectives and verbs) whilst reducing the number of documents, and in extension, processing time.

Analysing the lengths of the documents in terms of number of words (Figure 7.2) shows no significant difference between $\mathbb{WE}^{\text{sim}}_{\text{geo}}$ and $\mathbb{WE}^{\text{sim + craik/bio}}_{\text{geo}}$ (Welch two sample t-test: $p = 0.698$). However, the length of identified similar *Geograph* image descriptions was found to be significantly longer (Welch two sample t-test: $p < 0.01$) when prefiltering ($\mathbb{GEO}^{\text{sim + craik/bio}}_{\text{we}}$) compared to the whole dataset of similar documents ($\mathbb{GEO}^{\text{sim}}_{\text{we}}$). In other words, prefiltering the *Geograph* corpus leads to significantly higher cosine similarity scores and significantly longer documents in the resulting corpus. Thus, only the corpus filtered with Craik's list adjectives and biophysical nouns is used for further analyses.

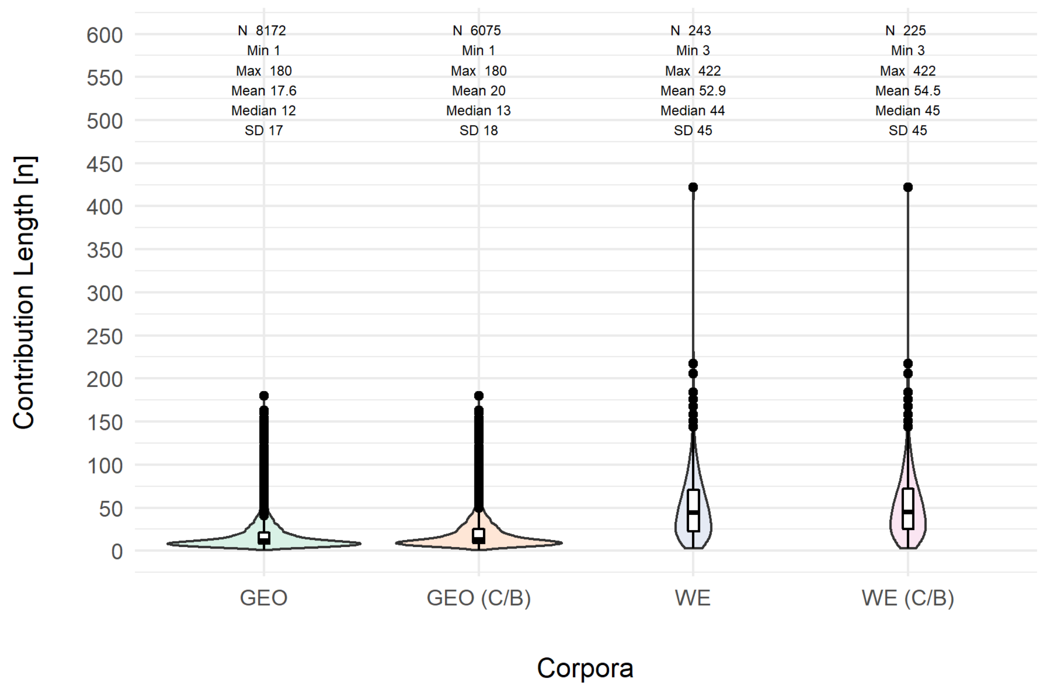


Figure 7.2: Document lengths in terms of number of words. (C/B): dataset prefiltered using Craik's list and biophysical terms

7.2 Comparing similar documents to general English

To further investigate the similarity of the $\mathbb{WE}_{geo}^{sim + craik/bio}$ comments in terms of domain specificity and content, both $\mathbb{WE}_{geo}^{sim + craik/bio}$ and $\mathbb{GEO}_{we}^{sim + craik/bio}$ were compared to the BNC corpus[5] of general English natural language (Kilgarriff, 1995). Using χ^2, terms were identified that were significantly more frequent in a particular corpus. Specifically, following three cases were compared:

1. terms that are significantly more frequent in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus but not significantly more frequent in the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus compared to $\mathbb{BNC}$

2. terms that are significantly more frequent in the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus but not significantly more frequent in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus compared to $\mathbb{BNC}$

3. terms that are significantly more frequent in both the $\mathbb{WE}_{geo}^{sim + craik/bio}$ and $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpora compared to $\mathbb{BNC}$

The results show that there are a number of nouns ($n = 24$), adjectives ($n = 10$) and verbs ($n = 10$) that are significantly more frequent in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus, whilst not being significantly more frequent in the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus, compared to $\mathbb{BNC}$. The most frequent nouns *"window"*, *"plant"*, *"home"* and *"balcony"* indicate that $\mathbb{WE}_{geo}^{sim + craik/bio}$ captures more everyday lived environments. The adjectives show that colours may be more prominent in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus (e.g. "*red*", "*white*", "*pink*") as well as locations relative to a certain object such as a house (e.g. "*front*", "*back*"). The verbs hint at *Window Expeditions* being more able to capture other sensory experiences (e.g. "*hear*", "*feel*") as well as including more human related activities (e.g. "*live*", "*visit*", "*sit*", "*enjoy*").

Exploring the terms that are significantly more frequent in the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus, whilst not being significantly more frequent in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus, compared to $\mathbb{BNC}$ shows a larger number of identified nouns ($n = 141$), adjectives ($n = 73$) and verbs ($n = 95$). The notably larger number of terms can be attributed to the considerably larger $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus containing many terms missing from the $\mathbb{WE}_{geo}^{sim + craik/bio}$ corpus. The results show terms such as *"farm"*, *"valley"*, *"country-side"*, *"woodland"* and *"pasture"* to belong to the most frequent. These terms indicate that the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpus seems to capture more rural or natural landscapes.

[5]In the following the notation $\mathbb{BNC}$ is used to refer to this corpus

In addition, when looking through all the identified terms, more landscape specific terminology such as *"burn"*, *"forestry"*, *"quarry"*, *"marsh"* and *"meadow"* is found. Inspecting the adjectives hints at two main points. Firstly, the overrepresentation of positively connotated adjectives (e.g. "*attractive*", "*brilliant*", "*colourful*", "*fantastic*", "*glorious*", "*golden*", "*interesting*", "*lovely*", "*magnificent*", "*peaceful*", "*pleasant*", "*spectacular*", "*splendid*", "*wonderful*") points towards the $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ corpus being heavily biassed towards positive sentiments. Secondly, the identified adjectives contain many opposites (e.g. "*close*" & "*far*", "*near*" & "*far*", "*dull*" & "*vivid*", "*wet*" & "*dry*", "*flat*" & "*steep*", "*fine*" & "*rough*", "*early*" & "*late*") suggesting that in the $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ corpus, landscapes are often described using opposites to delineate certain landscape features or to highlight particularly salient characteristics (e.g. the flat valley floor bounded by steep mountains). The identified verbs highlight the importance of the visual dimension in the $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ corpus with *"view"* and *"show"* belonging to the most frequent verbs. This is not surprising as the $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ corpus consists of descriptions of representative landscape images and is thus biassed towards the visual dimension.

These results suggest that both $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ and $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ describe the surroundings of an observer and are landscape specific. However, it also suggests that the $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ and $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ corpora describe different landscapes, with $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ capturing more ordinary everyday lived landscapes whilst $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ describes representative landscape features of a given extent.

To further investigate how both corpora differ from natural language, nouns, adjectives and verbs that are significantly more frequent in $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ as well as $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ compared to the $\mathbb{BNC}$ corpus of natural language were identified. The significantly more frequent nouns ($n = 76$) show that both corpora capture landscape specific terms. Salient terms such as *"tree"*, *"house"*, and *"building"* show high frequencies in both corpora indicating that both $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ as well as $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ capture particularly salient features in everyday lived landscapes. Other terms such as *"garden"*, *"sky"* and *"bird"* seem to be more frequent in $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$, whereas *"field"*, *"view"* and *"road"* are more frequent in $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$. This underlines the assumption that in both corpora participants describe landscape specific features, however they differ in what they choose to describe. This is to be expected as *Window Expeditions* specifically focuses on everyday lived landscapes whereas *Geograph* aims to collect representative landscape images and descriptions covering the whole of the UK, where many areas are uninhabited. Identified adjectives ($n = 30$) that are significantly more frequent in $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ as well as $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ compared to $\mathbb{BNC}$ revolve around colours (e.g. "*green*", "*blue*", "*grey*", "*brown*", "*yellow*") and other terms describing size, meteorological phenomena and topography (e.g. "*small*", "*little*", "*warm*", "*cold*", "*sunny*", "*bright*", "*bare*", "*residential*"). Finally, the verbs ($n = 20$) show a very similar distribution with the terms *"look"* and *"see"* being most frequent in both corpora, highlighting the importance of visual perception in both corpora. These results strengthen the argument that the proposed workflow of identifying similar natural language documents - given a small initial dataset - is possible through signifier terms and vectorisation of natural language documents to perform cosine similarity calculations.

7.3 Latent Dirichlet allocation topic modelling

To explore the emergent topics in both corpora, clusters of terms were identified using latent Dirichlet allocation (LDA) topic modelling. Models for a range of number of clusters (1 - 9) were calculated to identify the number of clusters with the highest coherence score. When inspecting the individual coherence scores, setting a total of nine clusters shows high coherence scores within both $\mathbb{WE}^{\text{sim + craik/bio}}_{\text{geo}}$ and $\mathbb{GEO}^{\text{sim + craik/bio}}_{\text{we}}$. Visual inspection of the topic clusters shows that individual clusters represent various topics, most of which are landscape specific. To compare the emergent topic clusters of *Window Expeditions* and *Geograph*, the cosine similarity scores between individual clusters were calculated and plotted (cf. Figure 7.3). For each cluster a vector was generated in which positions correspond to terms and values represent respective probabilities of terms being in a given topical cluster.

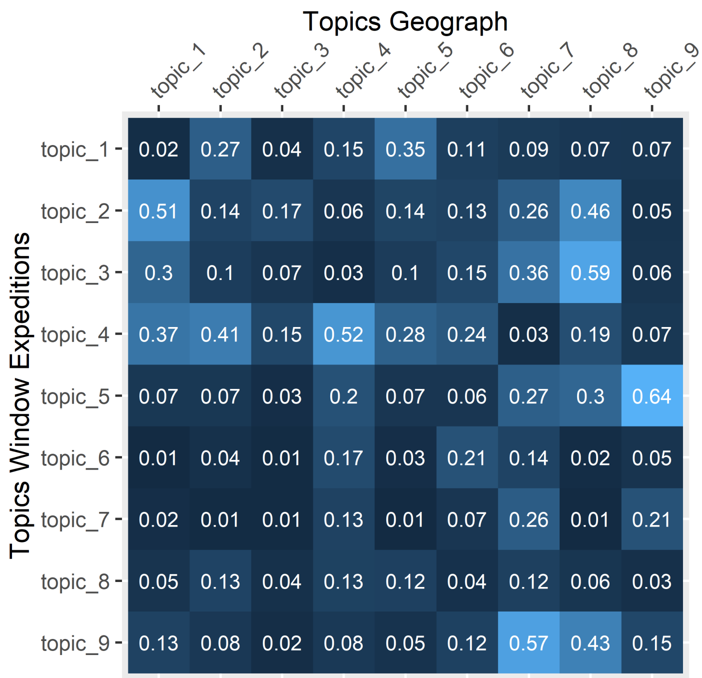


Figure 7.3: Matrix showing the cosine similarity scores between *Window Expeditions* and *Geograph* topic clusters identified from LDA topic modelling

Cosine similarity scores were calculated between all nine $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ and $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ clusters, resulting in a 9 x 9 cosine similarity matrix. In the following, four interesting and distinct topical clusters emerging from $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ were identified and compared to the most similar clusters emerging from $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ and identified through the topic cluster cosine similarity scores.

In $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ emergent cluster two (t_2) captures topics related to everyday lived landscapes in residential areas and shows high similarity (cosine similarity: 0.51) to emergent cluster one (t_1) in $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$ (cf. Figure 7.3). Both clusters show similar salient terms such as *"house"*, *"tree"*, *"building"* and *"road"* or *"street"*, indicating both clusters represent the general topic of everyday lived landscapes (Figure 7.4).

(a) Topic **t_2** in $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ (b) Topic **t_1** in $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$

Figure 7.4: Wordclouds of clusters representing the topic *urban and residential* landscapes

(a) Topic **t_4** in $\mathbb{WE}_{\text{geo}}^{\text{sim + craik/bio}}$ (b) Topic **t_4** in $\mathbb{GEO}_{\text{we}}^{\text{sim + craik/bio}}$

Figure 7.5: Wordclouds of clusters representing the topic *rural and natural* landscapes

The cluster (t_4) in $\mathbb{WE}_{geo}^{sim + craik/bio}$ shows highest similarity (cosine similarity: 0.52) with cluster (t_4) in $\mathbb{GEO}_{we}^{sim + craik/bio}$. Terms related with rural or natural landscapes such as *"forest"*, and *"village"* are found in the former, terms relating to natural landscapes such as *"loch"*, *"pasture"* and *"cloud"* in the latter and the terms *"mountain"*, *"hill"* and *"view"* are important in both (cf. Figure 7.5). These clusters seem to represent the general topic of rural and natural landscapes people visit in a recreational or leisurely capacity as opposed to the aforementioned clusters which represent more everyday lived landscapes.

Another noteworthy overlap (cosine similarity: 0.57) are cluster nine (t_9) in $\mathbb{WE}_{geo}^{sim + craik/bio}$ and cluster seven (t_7) in $\mathbb{GEO}_{we}^{sim + craik/bio}$. Both clusters revolve around the season of autumn and the autumnal colours seasonal changes entail (cf. Figure 7.6). The results show the terms *"tree"* and *"autumn/fall"* to be particularly salient in both clusters and the term "*colour*" to be highly salient in *Geograph* and represented in *Window Expeditions*. This suggests the two clusters represent the topic of seasonality, in particular the noticeable seasonal changes in autumn. This also goes to show the importance of visual change in landscapes in terms of colours when perceiving landscapes

Finally, cluster five (t_5) in $\mathbb{WE}_{geo}^{sim + craik/bio}$ and the cluster nine (t_9) in $\mathbb{GEO}_{we}^{sim + craik/bio}$ were found to be similar (cosine similarity: 0.64) with the term *"snow"* being highly salient and other snow related terms such as *"cover"*, *"cold"* and *"rain"* appearing in both clusters (cf. Figure 7.7). This hints at weather related phenomena being frequently described in both $\mathbb{WE}_{geo}^{sim + craik/bio}$ as well as $\mathbb{GEO}_{we}^{sim + craik/bio}$ and snowfall or the presence of snow being particularly salient in both corpora.

These results underline two main points important for this chapter. First and foremost, similar topics emerge from both corpora when performing LDA topic modelling. This further strengthens the argument that the documents identified as being similar to *Window Expeditions* do indeed capture similar topics. Especially noteworthy is the high similarity of some clusters and the topics they represent. Comparing the clusters suggests that even though the $\mathbb{GEO}_{we}^{sim + craik/bio}$ documents are notably shorter in terms of number of words, both corpora seem to capture similar salient landscape features. Secondly, both in the $\mathbb{WE}_{geo}^{sim + craik/bio}$ as well as the $\mathbb{GEO}_{we}^{sim + craik/bio}$ corpora, the topics of everyday lived landscapes, rural or more natural environments, the season of autumn and respective colours as well as the importance of snow emerge as highly salient. The performed comparisons all arguably point towards the presented approach being a viable and powerful workflow of using a moderated high quality active crowdsourced dataset to identify similar documents in other large collections of natural language.

(a) Topic **t_9** in $\mathbb{WE}_{geo}^{sim + craik/bio}$ (b) Topic **t_7** in $\mathbb{GEO}_{we}^{sim + craik/bio}$

Figure 7.6: Wordclouds of clusters representing the topic *autumn and colours* in landscapes

(a) Topic **t_5** in $\mathbb{WE}_{geo}^{sim + craik/bio}$ (b) Topic **t_9** in $\mathbb{GEO}_{we}^{sim + craik/bio}$

Figure 7.7: Wordclouds of clusters representing the topic *snow and weather* in landscapes

7.4 A novel approach to generating domain specific corpora

This chapter presented a workflow for generating large domain specific corpora based on a small curated high quality corpus. Documents from multiple corpora ($\mathbb{WE}$, $\mathbb{GEO}$, $\mathbb{WIKI}$) were translated to a multidimensional vector space and subsequently compared through cosine similarity calculations to identify most similar documents. Visually inspecting *Geograph* descriptions with high cosine similarity scores to *Window Expeditions* contributions shows the identified documents to be highly similar in terms of underlying semantics and landscape relevance. This suggests that the multidimensional vector representations of documents do indeed capture underlying semantics regarding landscapes. The significantly lower cosine similarity score distribution when comparing *Window Expeditions* to a corpus with limited landscape relevance ($\mathbb{WIKI}$) underlines this assumption.

Both *Window Expeditions* and *Geograph* contain rich landscape relevant information and were found to differ from general English natural language ($\mathbb{BNC}$). However, the two corpora take slightly different perspectives on landscapes: the former ($\mathbb{WE}$) focuses on everyday lived landscapes whereas the latter ($\mathbb{GEO}$) contains more representative landscape image descriptions. Nonetheless, the results of the latent Dirichlet allocation topic modelling show that both corpora capture very similar topics, highlighting the success of the proposed workflow. This thesis has thus successfully crowdsourced and curated a small and high quality corpus of everyday lived landscape descriptions which was subsequently used to generate a large corpus of landscape relevant documents. This approach opens the door to novel large scale inquiries into landscapes using various sources of natural language to generate and analyse large landscape relevant corpora.

8 Discussion and Limitations

> *Our knowledge has made us cynical. Our cleverness, hard and unkind. We think too much, and feel too little. More than machinery we need humanity.*
>
> — **Charlie Chaplin**
>
> (Comedian)

How individuals perceive landscapes affects their well-being and behaviour (Abraham et al., 2010). Thus, understanding individual perceptions of landscapes is important for inclusive decision and policy making (Scott, 2003; Tudor, 2014), especially in everyday lived landscapes where we spend most of our lives. However, the ways in which landscape perception data are to be collected is debated. This thesis aims to address the overarching question of how everyday lived landscape perceptions can be collected, extracted and analysed from actively crowdsourced natural language landscape descriptions collected through gamified applications, as a novel complementary approach of landscape perception data generation. This chapter ties together the results of this thesis with accompanying literature in light of the research questions set out in the introduction and background (cf. Chapters 1 & 2).

8.1 Gamification in landscape perception data generation

Data on how people perceive landscapes, including the sensory experiences of people in landscapes as well as the perceived cultural ecosystem services, have traditionally been collected through surveys, questionnaires, interviews and free-listing approaches (Bromley, 1981; Ruff and Maddison, 1994; Hastak et al., 2001; Jones, 2007; Swanwick, 2009; Krueger et al., 2012; Wartmann et al., 2018; Fagerholm et al., 2020), resulting in rich domain specific datasets. However, financial and time constraints have been identified as restricting factors in more traditional approaches as opposed to contemporary crowdsourcing and citizen science efforts (Kraut et al., 2004; Behrend et al., 2011; Dergousoff and Mandryk, 2015; Edgar et al., 2016). Extracting sensory experiences or cultural ecosystem services from actively and gamefully crowd-sourced natural language landscape descriptions has received little attention to date. The results of this thesis show that such actively contributed landscape descriptions do in fact capture a wide range of biophysical elements, sensory experiences and cultural ecosystem services found in comparable studies (cf. Millennium Ecosystem Assessment, 2005; Bieling, 2014; Wartmann and Purves, 2018; Fagerholm et al., 2020). This highlights the potential of using volunteered landscape information as a potent data source for extracting various perceived cultural ecosystem services as well as more in-depth information about how, where and why these are perceived.

This thesis transcends contemporary methods of active crowdsourcing by additionally exploring and incorporating gamified elements to increase user motivation and to diversify participant demographics. Gamification has been incorporated in various crowdsourcing projects and has been shown to increase the amount and quality of contributed data (cf. Morschheuser et al., 2017). The results of this thesis however, paint a more varied picture. On the one hand, the in-situ landcover classification data collected through the implemented highly gamified application *StarBorn* (cf. Chapter 3.3) shows high contribution rates of participants, in line with the literature stating gamification motivates participation (cf. Hamari et al., 2014; Fritz et al., 2017; Morschheuser et al., 2017). However, a negative correlation between the number of contributions per participant and their respective agreement rates was found in contributions to *StarBorn*, contradicting the hypothesis that gamification generally increases data quality. The literature shows multiple examples of gamification not affecting or even decreasing contribution quality, for example due to users maximising in-game performance, time constraints through increasingly challenging game-play and users being deterred from more difficult tasks (Eickhoff et al., 2012; Dergousoff and Mandryk, 2015; Carlier et al., 2016). The natural language descriptions of everyday lived landscapes collected with the minimally gamified application *Window Expeditions* on the other hand show contribution counts comparable with traditional methods (Bieling, 2014; Wartmann and Purves, 2018; Fagerholm et al., 2020), indicating no noticeable increase by incorporating gamified elements.

Nonetheless, the overall data quality of these contributed landscape descriptions was found to be high with rich natural language descriptions capturing a large variety of landscape specific features. The results of this thesis arguably show the quality of contributions generated through *Window Expeditions* to be on par with carefully compiled datasets in comparable research including selected short stories (Bieling, 2014), interviews (Wartmann and Purves, 2018) or public participation geographic information systems (Fagerholm et al., 2020). However, most participants contributed only once or twice rendering individual participant contribution quality over time estimations obsolete. This underlines the importance of carefully considering questions of user motivation and user retention, which has been found difficult in crowdsourcing and citizen science in general (See et al., 2016; Fritz et al., 2017; Morschheuser et al., 2017). In addition, a higher number of participants can be recruited with increased promotional efforts, which should be considered in further implementations.

The results from *StarBorn* and *Window Expeditions* suggest three main points in need of further consideration. Firstly, highly gamified applications such as the implemented location-based game *StarBorn* attract a more specific crowd who seem to be engaged over a longer period of time compared to less gamified applications such as *Window Expeditions*. This is in line with the literature showing the different demographic composition of individuals who are attracted by highly gamified solutions (Eickhoff et al., 2012; Morschheuser et al., 2017; Fritz et al., 2017) compared to the audience of more traditional citizen science projects (Curtis, 2018; Blake et al., 2020). The results of this thesis show that *StarBorn* attracted a predominantly male audience whereas *Window Expeditions* was able to motivate a balanced audience of male and female participants. This can potentially be attributed to differences in preferences of gamified elements (cf. Hartmann and Klimmt, 2006; Codish and Ravid, 2017) such as male participants generally preferring competition more than female users (Hartmann and Klimmt, 2006), or it could merely be an artefact of the audience reached through our promotional efforts. However, both *StarBorn* and *Window Expeditions* were able to motivate a younger audience than commonly represented in landscape perception data which hints at the potential of including overlooked demographics in data generation with playful applications (cf. Martella et al., 2015; Morschheuser et al., 2017; Bubalo et al., 2019).

Secondly, collecting data on predefined categories such as in *StarBorn* leads to noticeably more, albeit less rich data than collecting natural language such as in *Window Expeditions*. This is in line with studies showing the detrimental effect on user motivation and retention when users feel overburderend in gamified crowdsourcing applications or citizen science projects in general (Dergousoff and Mandryk, 2015; West and Pateman, 2016; Curtis, 2018). However, the literature also states that a lower number of rich natural language contributions can lead to insights otherwise overlooked when using predefined categories and emphasises the value of small and carefully curated data collections such as short stories (Bieling, 2014) and interviews (Wartmann and Purves, 2018). In addition, gamification may have motivated more diverse contributions ranging from creative and elaborate poetic descriptions to very short factual statements (cf. Woodyer, 2012; Morschheuser et al., 2017).

Lastly, the results suggest that higher degrees of gamification can lead to decreasing contribution quality over time. This calls for special consideration and deliberation on where gamified elements can lead to an increase in user motivation, and where gamification might lead to unwanted effects such as decreased contribution quality. How to ensure data accuracy and quality has been a topic of interest in crowdsourcing and citizen science projects with participant peer reviewing, gold standard testing and moderation being the most widely adopted approaches (cf. Dergousoff and Mandryk, 2015; Carlier et al., 2016; Morschheuser et al., 2017).

Future efforts in implementing gamified crowdsourcing applications should thus arguably pursue a twofold data generation strategy: incorporating predefined categorisation tasks (such as landcover judgements as in *StarBorn*) as well as more time consuming tasks of contributing natural language data (such as landscape descriptions as in *Window Expeditions*) to engage the minimalist as well as the enthusiast participant. Further, future efforts should pay special attention to promotional efforts and targeted advertising to increase the number of participating users.

8.2 Capturing everyday lived landscapes

The results of the land cover analysis show that *Window Expeditions* successfully generated in-situ natural language descriptions of everyday lived landscapes. These landscapes have gained more attention during the extraordinary times of the global pandemic where many people were confined to their immediate surroundings (cf. Venter et al., 2020; Ugolini et al., 2020; Borkowski et al., 2021; Baumeister et al., 2022). However, everyday lived landscapes have received comparatively little attention in landscape perception research as opposed to idealised or particularly scenic landscapes found in other studies (Hanlon et al., 2011; Antrop, 2013). *Window Expeditions* was able to capture how people perceive their immediate surroundings which is highlighted by the significant differences in land cover types found in descriptions where participants reported being at home compared to being away from home. In addition, the exploration of frequent terms and their syntactic relations supports the mentioned assumption of users participating in-situ from everyday environments.

Capturing how individuals perceive everyday lived landscapes and the affordances thereof is becoming increasingly important seeing the global trend of urbanisation (Grimm et al., 2008) and the resulting decrease of time spent in natural landscapes (Cox et al., 2018). This is highlighted by the importance of complementing research on natural landscapes by "pay[ing] equal, or maybe even more, attention to the many cultural landscapes of the world that have been shaped by human agency over centuries" (Plieninger et al., 2014, p. 1). Moreover, everyday lived landscapes are not static, but constantly changing, driven by globalisation and immigration where individuals reproduce cultural identities through their interactions with landscapes and other individuals (Krase and Shortell, 2011). These changes in everyday lived landscapes provide opportunities for inclusion for example by planning for minorities, ensuring accessibility and encouraging social interactions (Rishbeth, 2001; Abraham et al., 2010; Steinfeld and Maisel, 2012). However, they can also span a field of tension for potential conflict between individuals or between anthropogenic use and natural dimensions (cf. Steinfeld and Maisel, 2012). It is thus of great value for policy and decision makers as well as urban planners to understand how individuals perceive and interact with their immediate surroundings. Particularly, to identify and address potential conflicts and make fair and inclusive decisions on future avenues of how everyday lived landscape can and should be used.

Natural language allows for freedom of expression and by annotating text sources we can analyse not only terms and respective co-occurrences, but also the relations and sentiments conveyed by the language used (cf. Bieling, 2014). This transcends traditional bio-physical approaches aiming for objective evaluation and characterisation of landscapes through sensor based approaches. However, the analysis of such a corpus is in no way trivial. Especially important is the question of how to address the semantic gap between the information a user wants to convey with a written landscape description, the actual meaning of the written text and the storage of said information in a structured and machine readable format. The semantic gap refers to the different internal representations (e.g. notions) and how these are conveyed with varying symbols (e.g. languages) (cf. Smeulders et al., 2000), showing similarities with the semiotic triangle (Ogden and Richards, 1923). The results of this thesis show that a playful approach of actively crowdsourcing natural language can give detailed insights into salient perceptions of landscapes and can uncover otherwise overlooked important features of everyday lived landscapes.

8.2.1 Comparing salient landscape elements in English and German

The analyses of the generated data suggests different elements of landscapes to be particularly salient in everyday lived environs as opposed to more idealised landscapes, typically favoured in landscape perception research (cf. Swanwick, 2009; Beza, 2010; Bruns et al., 2015; Menatti and Da Rocha, 2016; FOEN, 2020). A selection of the nouns, adjectives and verbs used to describe everyday lived landscapes were found to be similar in both English and German, hinting at important cross-linguistic commonalities in perceived landscape features. *"Tree / Baum"* was found frequently in both English and German underlining the importance of urban greenery in everyday lived landscapes, which has been related to mental and physical well-being (cf. Daniel, 2001; Abraham et al., 2010; Hadavi et al., 2015; Menatti and

Da Rocha, 2016; Cox et al., 2018; Seresinhe et al., 2019). Other nouns appearing frequently across both languages include general features found in the everyday surroundings of participating users such as houses, gardens and streets which are described using a diverse vocabulary. This, in combination with the analysis of landcover types, strengthens the argument that participants did indeed take their time to experience and describe the landscapes available to them from home.

Further, verb lemmas such as "*see / sehen*", "*hear / hören*", "*play / spielen*" and "*run / laufen*" were found frequently in both English and German, pointing towards sensory experiences and certain activities being equally important in both German and English landscapes. Similar findings have been reported in the literature showing overlaps in perceived affordances between participants from different cultural and language backgrounds (cf. Fagerholm et al., 2020). However, the Eurocentric bias in the conceptualisation of commonly applied landscape perception frameworks calls for caution when generalising these results (cf. Pröpper and Haupts, 2014; Fraser et al., 2016).

The importance of curating signifier term lists specifically for landscapes was identified in 1972 when Craik (Craik, 1972) devised a list of landscape specific adjectives commonly used to describe landscapes. The results show that in the collected German as well as English corpora adjectives describing the size and quantity of landscape features seem to be particularly important. This is in line with the literature on landscape visual character assessments and may reflect the size and quantity of landscape features influencing complexity, coherence, disturbance and visual scale (Ode et al., 2008) and are thus important for the visual perception of landscapes. In addition, the results show that colours are frequently used to describe elements in both languages, indicating that colours in general are important descriptors of landscape features (cf. Lengen, 2015; Sadeghifar et al., 2019) with changing colours (e.g. leaves in fall) being highly salient. Further, the literature has found colours in landscapes to influence our emotional state to varying degrees depending on our socio-cultural background (Neale et al., 2021), making reported colours a potential proxy for well-being (e.g. grey vs. green).

The results also show lemmas with considerable differences in their frequencies when comparing languages. Terms that show considerable difference in rank when comparing English and German can be split into a number of clusters. Firstly, the results show concepts that might be more important in one language compared to another. These include terms such as *"meadow / Wiese"* in German and *"field / Feld"* in English which are both used to describe an open grassy area. Remembering the semiotic triangle (Ogden and Richards, 1923), this suggests that participants describing particular landscape features may use different symbols - including translated symbols - to communicate similar referents as a function of language.

These results emphasise the importance of moving away from the assumption that all cultures and languages conceptualise landscapes the same way and underline the need for more cross-linguistic investigations of landscapes (Mark et al., 2011; Burenhult et al., 2017).

Secondly, differences were found as a result of the chosen computational approach. Some terms such as the verb *"smell / riechen"* appear more frequently in German than in English due to English speaking participants commonly using the noun *"smell"* rather than the verb to describe olfactory experiences. On the other hand, the term *"today"* was annotated as a noun by the English part of speech tagging algorithm, whereas the German counterpart *"heute"* was annotated as an adverb. Thirdly, terms can have a variety of uses in different languages and the overlaps of usage can vary. For example, the term "*drive*" is most commonly used to denote the operating of a private motorised vehicle in English, whereas the translated term "*fahren*" can be used to describe the usage of a variety of transportation modes.

8.2.2 Salient landscape elements in context

To further investigate the terms and how they are used, graphs were created from the syntactic relationships found through dependency parsing. The resulting graphs present a summary of a term lemma's context within the corpus. Identifying a lemma's context is important to add additional information to a term (cf. Erk et al., 2013; Melamud et al., 2016) and has a long tradition in indexing systems such as the key-word-in-context (KWIC) method (Fischer, 1966). By qualitative inspection of the generated graphs, important concepts can be gleaned from the contexts of specific terms allowing for the exploration of shared ways in which highly frequent terms are described. The results show that trees are often not referred to by simply the term *"tree"* or *"vegetation"* but the type of tree is reported (e.g. *"oak tree"*, *"apple tree"*, *"pine tree"*). Similarly, buildings are often referred to using more detailed terminology (e.g. *"apartment building"*, *"office building"*, *"dorm building"*). Participants potentially use these composite terms to differentiate the perceived features from their respective surroundings and efficiently communicate the experienced surroundings. This is in line with the argument that "[...] the task of category systems is to provide maximum information with the least cognitive effort" (Rosch, 1978, p. 2). Discussions of basic level categories thus become important (Hajibayova, 2013), especially, questions of identifying basic level categories of everyday lived landscapes and if these remain stable within and over different socio-demographic and cultural groups. The results of this thesis suggest that particularly salient features of landscapes and important biophysical objects in landscapes are referred to in more detail, transcending mere basic level categories. For example, trees, birds and buildings (terms that are mentioned particularly frequently) are differentiated into their individual types or species whereas it appears less important to differentiate cars or clouds into their specific make and models or meteorological types.

8.2.3 Biophysical elements of landscapes

The cultural ecosystem framework used to guide the analyses of this thesis suggests that biophysical features "provide the physical and non-human components of [these] spaces, and the opportunities for cultural practices associated with them" (Fish et al., 2016, p. 212). Seeing the definition also emphasises the cultural affordances of biophysical elements, I have broadened the definition to include both perceivable *bio* (natural) features (e.g. trees, rivers, cliffs) as well as other *physical* (anthropogenic) features (e.g. roads, buildings, canals) and meteorological phenomenon (e.g. weather). This shows large overlaps with the concept of landscape elements which are stated to include "environmental features, such as landforms, water bodies and life forms; ecological dimensions (e.g., habitat); ephemeral qualities and dynamic environmental conditions, such as seasonal changes, time of day or cloud; and human-activity elements" (Dakin, 2003, p. 192).

Biophysical elements have been argued to be an integral part of cementing cultural aspects in ecosystem services (cf. Daniel et al., 2012) and thus are incorporated into contemporary frameworks (cf. Fish et al., 2016). However, the role of biophysical elements for the perception of landscapes has been debated since it has been argued that "landscapes are basically life-worldly aesthetic unities with symbolic meanings, arrangements of symbolic objects but not systems of interacting biophysical objects" (Kirchhoff, 2012, p. 1). Nevertheless, biophysical elements were often mentioned in contributed everyday landscape descriptions, calling for further investigation. The most frequently found categories of biophyiscal elements were *vegetation*, *built environment* and *weather / atmosphere*.

The results show that specific categories of biophysical elements were found significantly more often within contributions annotated as referring to specific sensory experiences or cultural ecosystem services. The biophysical category of *animals* was often found in combination with the sensory experience of *smell* and *sound* was often related to *moving objects*. This seems intuitive as animals are frequently perceived with a variety of odours (Porteous, 1985; Lefebvre, 1992; Hoover, 2009) and moving objects are commonly sound emitting vehicles of motorised transport (cf. Farina, 2014; Chesnokova et al., 2019). This points towards particular biophysical elements or unique configurations thereof influencing the perceived affordances within a landscape. However, additional research is called for to further our understanding of the relationships between perceived biophysical elements and perceived affordances.

8.2.4 Experiencing landscapes

Investigations into the visual perception of landscapes are common in landscape perception research (cf. Zube et al., 1982; Daniel, 2001; Ode et al., 2008; Koblet and Purves, 2020), which is not surprising seeing the dominance of the visual dimension for human perception in general (Porteous, 1985; Gibson, 1986). The importance of the visual in perceiving landscapes is underlined by studies on scenicness (cf. Seresinhe et al., 2018; Seresinhe et al., 2019) and visual landscape research (cf. Dakin, 2003; Ode et al., 2008) enjoying a prominent spot in landscape perception and preference research. The results of this thesis underline the importance of visual perception with the adjective *"see"* being the most frequently used verb lemma that is significantly more common in *Window Expeditions* compared to general English language and landscape image descriptions. In addition, the generated corpus complements traditional visual approaches by also capturing other dimensions such as sound, smell, taste and feel, which have been identified as important perceptual dimensions of experiencing places and landscapes (cf. Tuan, 1975; Porteous, 1985; Sepe, 2013; Quercia et al., 2015; Aiello et al., 2016).

This thesis has found visual sensory experiences to co-occur with auditory and haptic experiences, however, less often with experiences involving taste or smell. More recent explorations of the auditory dimensions of landscapes have led to inquiries into the positive aspects related to the presence or absence of sounds such as tranquillity or natural soundscapes (cf. Koblet and Purves, 2020; Herzog and Bosley, 1992; Andringa and Lanser, 2013) and the negative influences of sounds such as the detrimental effects of noise pollution (cf. Stansfeld and Matheson, 2003; Andringa and Lanser, 2013). The data collected through *Window Expeditions* strengthens the argument of sounds being important in how humans perceive their surroundings which holds true for everyday lived landscapes.

Especially noteworthy is the importance of birds within the auditory dimension of everyday lived landscapes, identified through the significant over-representation of the term bird within contributions annotated as referring to sounds. This is in line with the literature highlighting the importance of natural elements in urban contexts and how these influence happiness and well-being (cf. Abraham et al., 2010; Thompson, 2011; Vujcic et al., 2019). In addition, the results showing birds to be particularly salient are in line with findings indicating a higher bird diversity leads to increased well-being on par with the effects of having a higher income (Methorst et al., 2021).

Further, the haptic dimension was found in a number of contributions, albeit mostly related to weather phenomena. Weather or atmospheric related phenomena have been found to influence how landscapes are perceived and appreciated (Ingold, 2005; Półrolniczak and Kolendowicz, 2021) and the results suggest that these are also important in everyday lived landscapes. In *Window Expeditions*, weather is mostly described using high level categories suggesting participants include weather descriptions as a way of setting the scene through text, begging the question if contributors actually perceive the weather as an important part of a given landscape or if the weather is merely a background phenomenon.

Finally, a small number of studies have investigated smells and tastes of environments (Porteous, 1985; Lefebvre, 1992; Hoover, 2009; Quercia et al., 2015) and have shown the importance of the olfactory and taste dimensions in how landscapes are valued. However, the results presented in this thesis show that mentions of smells and tastes were rather rare, leading to the assumption that smells are less important for the perception of everyday lived landscapes. This may be a result of smells being taken for granted or not being noticed due to olfactory fatigue or smells being highly situational and dependent on the location of the smell emitter as well as temporal and meteorological variables (cf. Porteous, 1985). In addition, the surroundings of the contributors may not include noticeable landscape relevant odours since many of the contributors contribute from home (cf. Porteous, 1985).

8.2.5 Intangible dimensions of landscapes

Commonly, established frameworks are used to explore cultural ecosystem services of specific locations (cf. Millennium Ecosystem Assessment, 2005; Tudor, 2014; Fish et al., 2016; Fagerholm et al., 2020). The analyses of cultural ecosystem services within this thesis were generally guided by the framework of (Fish et al., 2016), however, other established frameworks exist (cf. de Groot et al., 2010; Paracchini et al., 2014; Pleasant et al., 2014). It must also be noted that cultural ecosystem services are often not fully integrated in general ecosystem services frameworks (Paracchini et al., 2014) due to their intangible nature. However, recent efforts of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) build upon the Ecosystem Services approach by highlighting the importance of culture in ecosystem debates and including local as well as indigenous knowledge in their framework: Nature's Contributions to People (NCP) (Díaz et al., 2018).

The choice of framework greatly influences the performed analyses and thus, this thesis focuses on the cultural ecosystem services in light of the sensory experiences in landscapes, salient biophysical elements as well as emergent intangible dimensions perceived in the everyday lived landscapes of participants. The results show *recreation* being the most frequently mentioned cultural ecosystem service, which has consistently been found in the literature (Bieling, 2014; Fagerholm et al., 2020). This points towards recreational services of landscapes being important for participants, especially in easily accessible local recreational areas such as urban parks (Scholte et al., 2018; Hansen, 2021; Wartmann et al., 2021a).

A noticeable number of contributions to *Window Expeditions* also contained implicit references to tranquillity, which has been found to be an important part of landscapes offering an escape from the more fast paced life of modern societies (Herzog and Bosley, 1992; Swanwick, 2009; Wartmann et al., 2019; Chesnokova et al., 2019; Fagerholm et al., 2020; Wartmann et al., 2021b). Tranquillity is commonly regarded as a dimension of recreational cultural ecosystem services (cf. Millennium Ecosystem Assessment, 2005; Hansen, 2021), however, this category emerged as a separate dimension during the iterative annotation process performed as part of this thesis (cf. Chapter 5). The cultural ecosystem service of heritage was frequently annotated, which can be expected in mostly urban environments (cf. Tengberg et al., 2012). The results point towards mostly anthropogenic objects being perceived as having some form of cultural heritage value, which is in line with the literature (cf. Capelo et al., 2012; Oteros-Rozas et al., 2018). The cultural ecosystem services of inspiration and religious values were annotated less frequently. Definitions of inspiration in terms of cultural ecosystem services usually describe inspiration as provoking thought or reflection (Millennium Ecosystem Assessment, 2005; Bieling, 2014; Baumeister et al., 2020). The scarcity of this dimension may be due to inspiration being a state of mind which is hard to define or describe (Thrash and Elliot, 2003), especially in written text, and it being a less clear category in terms of annotation guidelines. Religious values are also highly dependent on the annotation guidelines with many structures such as synagogues, mosques and churches clearly laden with religious values (Verkaaik, 2014). However, participants may mention such structures for their landmark value and not necessarily their religious connotations seeing religious structures are easily distinguishable from their surroundings (Bartie et al., 2015).

8.3 Identifying landscape relevant documents with sentence-transformers

Research on landscape perception and preference has led to important insights into how people and their surroundings are intertwined. Contemporary studies are commonly based on some underlying dataset incorporating diverse perspectives through public participation (cf. European Landscape Convention, 2000; Bubalo et al., 2019). However, many approaches struggle with motivating enough participants for large scale analyses, potentially resulting in more localised studies with some exceptions (e.g. Fagerholm et al., 2020). Nevertheless, inquiries into landscape perceptions need rich and high quality datasets.

This thesis has demonstrated the potential of using natural language landscape descriptions and computational natural language processing approaches in combination with iterative annotation methods to extract valuable landscape relevant data. However, landscape specific natural language corpora are scarce whereas textual content that is not explicitly generated for landscape perception and preference research can be found in abundance. This abundance of other sources of natural language corpora calls for efficient methods of filtering through large text collections and identifying potentially landscape relevant documents. This thesis was able to show that by translating the high quality contributions collected through *Window Expeditions* to a multidimensional vector space with sentence-transformers and comparing the generated vectors with vectors representing documents in other collections, similar documents can be found. This is in line with the general literature on vectorisation of text to identify similar textual content (cf. Pennacchiotti and Gurumurthy, 2011; Boyack et al., 2011; Takano et al., 2020). Particularly noteworthy is the reduction in processing time and the increase in average similarity by including predefined lists of biophysical elements and landscape specific adjectives.

This thesis goes to show that there are considerable overlaps of salient topics in the actively crowdsourced *Window Expeditions* corpus and the collection of computationally identified similar documents. The latent Dirichlet allocation topic modelling results highlight these overlaps and show that the topics of "*urban and residential landscapes*", "*rural and natural landscapes*", "*autumn and colours in landscapes*" and "*snow and weather in landscapes*" emerge as salient in both the original and the computationally identified corpora. These topics have been found to be particularly important in the landscape perception literature (cf. Tuan, 1975; Zube et al., 1982; Ingold, 2005; Hunziker et al., 2007; Antrop, 2013; Bruns et al., 2015; Vicenzotti et al., 2016), suggesting that the computational approach of identifying landscape relevant documents shows potential. However, it must also be pointed out, that the Geograph corpus was used, which is a collection of image descriptions of representative landscape images. Further studies should investigate the approach proposed in this thesis on other collections of textual content such as social media or books.

8.4 Comparing participatory approaches

When exploring new methodological approaches to generating scientific data it is common practice to compare the generated data and the results with existing well established approaches. Of particular interest is how the presented approach of gamified active crowdsourcing compares to other participatory approaches of landscape relevant data generation in terms of contributing users as well as the characteristics of the collected data.

Established participatory approaches of landscape perception data generation revolve around free-listing experiments (Wartmann et al., 2015; Komossa et al., 2020; Wartmann and Purves, 2018), public participation geographic information systems (Brown and Brabyn, 2012; Fagerholm et al., 2020), active and passive crowdsourcing (Bubalo et al., 2019; Ghermandi and Sinclair, 2019) and analysing text sources including short stories (Bieling, 2014), alpine yearbooks (Derungs and Purves, 2014) and content scraped from the web (Koblet and Purves, 2020). Comparing *Window Expeditions* to mentioned approaches reveals interesting similarities as well as notable differences summarised in Table 8.1. Freelisting experiments are commonly conducted with a relatively small number of individuals (e.g. 89 participants (Wartmann et al., 2015), 402 participants (Komossa et al., 2020), 300 participants (Wartmann and Purves, 2018)), whereas PPGIS approaches have seen hundreds to thousands of contributors (e.g. 608 participants (Brown and Brabyn, 2012), 2301 participants (Fagerholm et al., 2020)). Active crowdsourcing datasets such as EmoMap, Geograph and Mappiness range between hundreds to tens of thousands of participants (e.g. 193 participants in EmoMap (Bubalo et al., 2019), >12000 participants in Geograph (Chesnokova and Purves, 2018), 66621 participants in Mappiness (Bubalo et al., 2019)) and passively crowdsourced datasets such as social media were found to include data from varying numbers of contributors depending on the research question and study area (e.g. 651 users (Oteros-Rozas et al., 2018), 4174 users (Richards and Tunçer, 2018), >1000000 users on social media in general (Van Zanten et al., 2016)). Studies using text sources as underlying data are varied in terms of number of contributing users. Assuming each article is contributed by a different individual and disregarding the commonly observed tendency towards highly active contributors (Ghermandi and Sinclair, 2019), these range from a small number of short stories (14 stories (Bieling, 2014)) to many thousands in blogs (e.g. 25000 articles (Derungs and Purves, 2016)), yearbooks (e.g. 10000 articles (Derungs and Purves, 2016)) and first person landscape perceptions scraped from web-sources (e.g. 6870 texts (Koblet and Purves, 2020)). The analysed *Window Expeditions* corpus consists of 638 contributions uploaded by 514 users and therefore is most similar to freelisting and PPGIS efforts in terms of number of contributors.

Contributions are either contributed in-situ as is common in freelisting experiments, active (and to some extent passive) crowdsourcing as well as in select text sources (cf. Wartmann and Purves, 2018; Chesnokova and Purves, 2018), or ex-situ as is commonly the case with PPGIS and most text sources (Brown and Brabyn, 2012; Bieling, 2014; Koblet and Purves, 2020). *Window Expeditions* was implemented to capture in-situ contributions and thus compares well with similar approaches of active crowdsourcing.

Collecting information about the contributing users has been found invaluable to interpret participatory data (Bubalo et al., 2019), however, reports on socio-cultural or demographic information can vary greatly. Generally, freelisting experiments and PPGIS approaches collect user characteristics to varying levels of detail (Brown and Brabyn, 2012; Komossa et al., 2020). For crowdsourcing efforts and analysing text sources however, commonly little or no information on contributing users is available (Bieling, 2014; Derungs and Purves, 2016; Chesnokova and Purves, 2018; Bubalo et al., 2019; Koblet and Purves, 2020) making representative explorations of landscape perceptions difficult. *Window Expeditions* collects demographic information (age, gender, fluent languages of participants) in an attempt at striking a balance between group specific exploration of the data and not deterring users from participation with detailed user information questionnaires.

Approach	Participants	Demographics	Location	Data	References
Freelisting	10 - 1K	✓	In-situ	Lists of associated terms	(Wartmann et al., 2015; Komossa et al., 2020; Wartmann and Purves, 2018)
PPGIS	100 - 10K	✓	Ex-situ	Mapped locations of categorical data	(Brown and Brabyn, 2012; Fagerholm et al., 2020)
Active Crowdsourcing	100 - 100k	-	(In-situ)	Specific user generated content	(Chesnokova and Purves, 2018; Bubalo et al., 2019; Ghermandi and Sinclair, 2019)
Passive Crowdsourcing	100 - 1M+	-	Ex-situ	General user generated content	(Oteros-Rozas et al., 2018; Richards and Tunçer, 2018; Van Zanten et al., 2016; Bubalo et al., 2019; Ghermandi and Sinclair, 2019)
Text sources	10 - 10K+*	-	Ex-Situ (In-situ)	Natural language texts	(Bieling, 2014; Derungs and Purves, 2016; Koblet and Purves, 2020)
Window Expeditions	100 – 1K	✓	In-situ	Natural language landscape descriptions	(Baer et al., 2019; Baer and Purves, 2022)

Table 8.1: Table summarising comparable approaches of generating landscape relevant data according to the referenced literature. * Refers to the number of used documents or texts for the approach *Text sources*

One final point of comparison revolves around the type of collected data. PPGIS and active crowdsourcing approaches generally collect data on fixed categories (Brown and Brabyn, 2012; Chesnokova and Purves, 2018), whereas freelisting approaches focus on lists of spontaneous associations collected as lists of terms (Wartmann et al., 2015; Wartmann and Purves, 2018; Komossa et al., 2020). Passively crowdsourced datasets consist of general user generated content not contributed towards a specific research question or project (Van Zanten et al., 2016; Oteros-Rozas et al., 2018; Bubalo et al., 2019; Ghermandi and Sinclair, 2019). Efforts of exploring textual data commonly extract relevant information from a variety of text sources through human or computational annotation and can include both emergent topic identification as well as classifying the data into predefined categories (Bieling, 2014; Derungs and Purves, 2016; Koblet and Purves, 2020). *Window Expeditions* aims at a mixed approach of asking participants specifically to describe their everyday lived landscapes whilst remaining open by collecting natural language landscape descriptions. This allows for expressive freedom in contributions whilst remaining landscape relevant.

Overall, *Window Expeditions* successfully generated data comparable to traditional freelisting experiments and PPGIS in terms of numbers of participating users and is comparable to studies using text sources in terms of quality and richness of the generated data. This highlights the complementary nature of gamified active crowdsouring platforms such as *Window Expeditions* when generating landscape specific information, navigating the trade-off between quantity and quality of contributed information.

8.5 Limitations

A number of key limitations were observed whilst analysing the generated descriptions and interpreting the results. This section lays out these limitations and discusses potential ways of addressing the shortcomings in future research endeavours.

8.5.1 Validating contributions

When involving the general public in data generation efforts questions of data quality and credibility become important (Flanagin and Metzger, 2008). These questions have commonly been approached from two complimentary angles. Firstly, by comparing expert and non-expert contributions to a specific participatory effort where the literature has found non-expert contributions can be on par with traditional approaches in terms of credibility, accuracy and quality (Haklay et al., 2010; See et al., 2013). Secondly, by exploring non-expert users' contributions decoupled from expert contributions as valuable participatory and inclusive data sources, which have been found to be rich in underlying semantics and high in quality (Swanwick, 2009). *Window Expeditions* is accompanied by limitations in terms of the credibility of contributions as well as contribution locations. Firstly, the application does not record or transmit the exact coordinates of participants. Contributors are able to choose and set their location freely in the contribution process and only the identifier of a hexagonal area is recorded. This effectively means there is no way of directly validating the accuracy and quality of the locations potentially allowing users to falsify locations. Secondly, seeing that natural language allows for freedom of expression, assessing the accuracy and credibility of natural language landscape descriptions without local knowledge or reference data remains highly challenging. The application thus relies on human moderation to judge the credibility of locations as well as contents, which is not scalable past a limit (Ghosh et al., 2011). Credibility is a key characteristic of crowdsourced data (Flanagin and Metzger, 2008) and contributions to *Window Expeditions* were deemed credible if they are situated in populated areas and describe landscape features likely to be in the spatial context of the contribution area. However, locations were sometimes found to be of the landscape being described and not of the participant, highlighting the need for human judgement. Computationally identifying credible contributions remains a complex task, calling for the consideration of crowdsourcing credibility ratings in line with the literature (cf. Ghosh et al., 2011; Lampe et al., 2014). Location-based games could address this shortcoming since moving around in the real world is an integral part of game-play (de Souza e Silva, 2009; Neustaedter et al., 2013) and spatial information is particularly suited to be collected through such games (Matyas, 2007). In addition, users could be asked to upload one or multiple photographs of their surroundings which could be used to verify potentially questionable locations and descriptions.

8.5.2 Small datasets for big questions

Another set of limitations is related to the size of the generated and analysed corpus. *Window Expeditions* successfully motivated users to contribute around 650 in-situ natural language landscape descriptions in English, German and French. The number of collected descriptions exceeds that of similar work exploring narrative descriptions of landscapes through short stories (cf. Bieling, 2014) and is on a level of magnitude comparable to the number of contributions to public participation geographic information systems (cf. Fagerholm et al., 2020). However, the volumes of data collected through popular crowdsourcing projects such as Geograph (Chesnokova and Purves, 2018) are orders of magnitude higher, allowing for more representative analyses. A notable advantage of *Window Expeditions* is that the collected descriptions explicitly capture the physical aspects of perceived environs and their immediate value as well as perceived intangible dimensions. In addition, a cross-linguistic dataset was generated, albeit biassed towards English contributions. This highlights the success of our promotional efforts through predominantly English channels as well as the potential desire of participants to contribute in English as a general preference or the application not offering a participant's own language. Overall, contributions were mostly uploaded from North America and Europe generally reinforcing the uneven geography of internet content (Graham, 2014). The limitations of generating a rather small corpus of natural language landscape descriptions was partly addressed by showing small datasets can be used to computationally identify similar documents in other text collections, greatly increasing the number of potentially interesting and useful documents for the exploration of landscape perceptions.

8.5.3 Temporal aspects of landscape perceptions

A third key limitation of the presented work is the absence of information on temporal changes in how landscapes are perceived, arguably due to insufficient user retention and thus a lack of longitudinal data. Landscapes change over time through our actions in and interactions with natural and built up environments, and so do our perceptions of our surroundings. Landscapes are commonly characterised as temporal snapshots of static entities and research into spatio-temporal changes in how individuals perceive landscapes are lacking (cf. Hunziker et al., 2007; Hedblom et al., 2020). This can be attributed to the costly and time consuming nature of traditional data collection efforts. When inspecting landscapes through individual level perceptions, differences start to crystallise around the more interactional and intangible properties of landscapes. For example, whilst most people would agree that the Matterhorn is indeed a mountain in Switzerland, the way in which people would interact with the Matterhorn and the intangible dimensions of the Matterhorn in terms of the cultural ecosystem services associated with the Matterhorn would vary greatly (e.g. from a national symbol of Switzerland to the recreational value through tourism or mountaineering). These subjective perceptions of a specific landscape, especially the perceived cultural ecosystem services, can be highly dynamic and subject to change over time (cf. Gould et al., 2020). This shows similarities with literature on temporal considerations of sense of place, where it has been argued that commonly used frameworks neglect fast individual changes in how places are perceived (Raymond et al., 2017). Affordances have been proposed as a potential approach of complementing existing frameworks by capturing temporal changes in perceptions over varying scales (Raymond et al., 2017; Raymond et al., 2018).

8.5.4 Methodological limitations

The methods and approaches used to analyse the generated content within the scope of this thesis successfully generated meaningful results complimenting existing approaches (cf. Section 8.4). However, many of the methodological approaches implemented are accompanied by a number of limitations which must be addressed.

First and foremost, the natural language processing workflows presented within this thesis and the generated results are in need of critical reflection. Natural language processing pipelines are commonly trained on vast amounts of textual data where the type and genre of training data influences the results of a given task (Hovy and

Prabhumoye, 2021). This was found, for example, in part-of-speech tagging results for common terms such as the term "*today*" which was parsed as a noun and not an adverb, as well as ambiguous terms such as "*lot*" which was parsed as a noun (as in "*parking lot*") and never as an adverb or pronoun (as in "*lots/many*"). Wrongly tagged terms can lead to noticeable over-representations of particular terms. This training data bias is particularly prominent in more specific tasks such as dependency parsing (Garimella et al., 2019) and sentiment analyses (Kiritchenko and Mohammad, 2018), calling for caution when interpreting the results. Further, translating services are trained on specific corpora which influence how terms are translated (cf. Graham et al., 2020; Su et al., 2021). The accuracy of translations are particularly affected when translating single terms without further context as opposed to whole sentences (Reber, 2019). Translating *Window Expeditions* terms showed clear training data biasses within the machine translation system where for example the term "*home*" was translated to "*Startseite*" (as in "*home page*") and the term "*plant*" was translated to "*Anlage*" (as in "*power plant*"). These limitations of natural language processing call for considerations of curating landscape relevant corpora to capture landscape specific language which can be used to train natural language processing algorithms for future landscape perception research endeavours.

A second set of limitations concerns the quantitative analyses of the generated natural language landscape descriptions. X^2 analyses use underlying frequencies of terms in multiple corpora to identify statistically significant over- and underrepresented terms (Kilgarriff, 2001; Gries, 2009). However, depending on the size of respective corpora and the ways in which these were collated, in combination with chosen significance thresholds, results may vary considerably and significance values may easily be achieved reducing the meaningfulness of the results (cf. Bestgen, 2013). For example, the *Window Expeditions* corpus was compared to the British National Corpus (BNC) and significantly over- and underrepresented terms were identified. The results may however show noticeable differences if *Window Expeditions* were to be compared to a corpus of general American English. Further, corpora of collections of individual documents such as the generated landscape specific *Window Expeditions* corpus are susceptible to biases towards individual documents containing many occurrences of specific terms, calling for careful consideration of sampling decisions (cf. Oakes and Farrow, 2006).

A last set of methodological limitations relates to the chosen qualitative approaches of annotating the generated natural language. Qualitative approaches such as human annotation and qualitative coding rely on human interpretation, making such efforts subjective. Annotators are embedded in a cultural and social framing leading to conscious and unconscious biasses within annotations (cf. Carley, 1993). This primarily affects consistency over time and consistency between individuals in the ways in which a given document is annotated (Richards, 2009; Elliott, 2018).

Complex tasks such as "search[ing] for pertinent information within a larger response context" (Crittenden and Hill, 1971, p. 1079) remain challenging and coding validity as well as inter-annotator reliability can be low (Crittenden and Hill, 1971). However, through the chosen iterative approach, interannotator agreement was high in the presented work, albeit highly document dependant. For example, all annotators agreed that the sentence: "*In days of old it must have been a walled garden - old stone wall with red and green ivy.*" references the cultural ecosystem service of *heritage*. However, annotators could not agree whether the sentences: "*A flag flaps in the breeze.*" and "*A driver speeds by.*" reference an auditory or a visual sensory experience. To address subjective interpretations, qualitative approaches commonly create annotation guidelines to facilitate more cohesive judgements, especially in a multi-annotator setting (Charmaz, 2006; Richards, 2009; O'Connor and Joffe, 2020). The guidelines created to assist the annotation of the *Window Expeditions* corpus specify how specific categories and codes are to be annotated within a given document. Updating guideline documents and annotations through an iterative process is common practice and can lead to new insights through emergent categories (Charmaz, 2006; Elliott, 2018).

8.5.5 Critiques of common frameworks

Last but not least, the results of this thesis must be interpreted keeping the cultural embedding of theory, methods and frameworks in mind. This thesis includes a wide variety of academic literature and is based on a diverse set of frameworks, methods and theory. However, it must be kept in mind that the reviewed literature, and the therein presented theories, methods and frameworks, are written in a specific language in and for a specific cultural context incorporating knowledge from said cultural context.

The majority of contributions to *Window Expeditions* were in English and thus analyses were primarily performed on English corpora. This has important implications in regards to the contributions themselves and the natural language processing used to analyse these. Firstly, participating users contributed natural language landscape descriptions in the language of their choice. Since landscape perception and language are deeply intertwined (cf. Brabyn, 2009; Putten et al., 2020), the captured salient features of landscapes presented in this thesis describe how English and occasionally German speaking participants experienced and described landscapes. Generalising the results to other languages is not trivial and should be explored cautiously, especially seeing the large differences in landscape conceptualisations depending on language (cf. Burenhult, 2004; Brabyn, 2009; Burenhult et al., 2017; Fairclough et al., 2018). Further, the used natural language processing workflows showed subtle differences in how different languages were processed. This underlines another important consideration in regards to exploring languages: the computational approaches to analysing language are not equal in all languages or variations of a language and in extension cultural and socio-demographic contexts (cf. Hovy and Prabhumoye, 2021). Some languages such as English enjoy high prominence in research and development of natural language processing algorithms resulting in high benchmark scores, whereas other languages are lacking behind or natural language models are missing altogether (cf. Joshi et al., 2020; Hovy and Prabhumoye, 2021). This influences the results of downstream processing tasks and points towards a language and culture bias in computational efforts related to natural language. It is thus of utmost importance to be aware of these potential biasses, especially when using natural language as a proxy of understanding landscape perception. This calls for more cross-lingual studies in landscape perception and preference research.

Further, the concept of cultural ecosystem services, and ecosystem services in general, remains controversial and its legitimacy is questioned and debated. The shortcomings of neglecting disservices or negative affects on humans' social, mental and physical well-being have been pointed out (cf. McCauley, 2006; Lyytimäki and Sipilä, 2009; Dunn, 2010; Shapiro and Báldi, 2014). In addition, many studies on cultural ecosystem services are conducted using frameworks written *in* and *for* a specific cultural context, which may not be adequately transferable to studies in different cultural settings (cf. Cosgrove, 1998; Kirchhoff, 2012; Pröpper and Haupts, 2014; Fraser et al., 2016). This has led to ongoing debates of the cultural bias in current academic research on ecosystem services and calls for the consideration of alternative approaches of understanding the intangible dimensions of our environments. This may also be reflected in the presented research and results where, for example, cultural heritage elements were mostly annotated as anthropogenic structures of historic significance, whereas other cultures may perceive cultural heritage differently (cf. Olwig, 2005).

Mentioned shortcomings of cultural and demographic bias make generalising the results of this thesis to other languages precarious and further research is needed to examine cross-cultural differences in landscape perception and preference. One possible approach to remedy mentioned limitations is focusing on affordances. Since affordances are judgement free and landscapes are argued to be accompanied by a number of relational affordance properties (Heft, 2010), landscapes could be investigated through the distribution of individually perceived affordances and how these distributions differ within and between groups of individuals.

8.6 Revisiting research questions and key findings

After an in-depth discussion of the most important findings and a critical reflection on major limitations, this section comes full circle and directly answers the research questions with a summarising statement. The summarising statements are based on the findings of this thesis.

RQ1: How can we collect natural language landscape descriptions about everyday lived landscapes that capture the rich diversity found within and between cultures and socio-demographic groups through a gamified application?

The results of this thesis have shown active crowdsourcing to be a powerful approach to generating diverse corpora of landscape relevant natural language. In particular, location based features allow for the collection of rich datasets by motivating a heterogeneous group of participants to take part in specific locations, such as contributing data in-situ when at home, and participants seemed happy to do so. In addition, using the languages participants report on being fluent in as a cultural proxy allows further exploration of differences in perceptions dependent on language and, in some cases, culture. Seeing the only slight gamification of the application by incorporating points and badges, gamification seemed to have a negligible effect on number of contributions. However, adding more competitive and collaborative elements could potentially increase user motivation and retention and needs further investigation.

RQ2: How can we analyse a rich corpus of actively crowdsourced natural language landscape descriptions of participants' everyday lived landscapes using both quantitative and qualitative methods and what added benefit does such a dataset provide?

By collecting in-situ natural language descriptions about perceived and experienced landscapes through a slightly gamified active crowdsourcing platform, rich insights into various landscape relevant dimensions can be gleaned. The results highlight the detailed insights into landscape perception that computational natural language processing workflows allow. In particular, this thesis has presented how salient landscape elements can be extracted from unstructured text through χ^2 analyses and ways in which a salient term's context can be explored through a graph or network. Quantitative statistical analyses have successfully been applied to give valuable insights into significantly over- and underrepresented terms, telling us something about the domain specificity of the generated corpus as well as highlighting particularly important landscape dimensions. Qualitative coding and annotation approaches were incorporated to complement quantitative methods and allow for deep insights into sensory experiences in landscapes as well as exploring perceived intangible dimensions of landscapes. Overall, this thesis has shown that a careful combination of simple and complex computational methods, complemented by human annotation approaches, can facilitate detailed inquiries into landscape specific natural language and uncover nuances commonly overlooked by traditional sensor based explorations of landscape.

RQ3: How can a carefully curated and annotated corpus of natural language landscape descriptions be used to identify similar landscape specific documents in other text collections?

The implemented active crowdsourcing platform *Window Expeditions* successfully generated a rich corpus of landscape relevant natural language, albeit the generated dataset was rather small. Thus, ways in which the small generated high quality corpus could support identifying landscape relevant documents in large corpora were explored. This thesis demonstrates a workflow of using sentence-transformers to translate crowdsourced landscape specific natural language descriptions to vectors, which are subsequently compared to the vectors of other documents using cosine similarity calculations. This allows for the identification of documents with similar underlying semantics, in this case landscape relevance. Using sentence-transformers and cosine similarity scores, this thesis successfully complemented the initial small high quality actively crowdsourced dataset with computationally identified similar documents in other corpora. In addition, the results suggest that pre-filtering corpora potentially containing landscape relevant documents with lists of signifier terms can reduce processing time whilst preserving high quality results.

Outlook and Conclusion

9

> *Everything is related to everything else, but near things are more related than distant things.*
>
> — **Waldo Tobler**
>
> (Geographer)

9.1 Future work

This thesis has presented a foundation of preliminary work on gamified active crowdsourcing in landscape perception research on which future efforts can build. In the following, I present a few future research avenues that complement or elaborate the findings of this thesis.

Firstly, the literature suggests that how landscapes are conceptualised through language can vary, within and between broader geographic regions such as Europe (Mark et al., 2011; Putten et al., 2020). This is of particular interest when analysing cultural ecosystem services of different landscapes and languages (cf. Fagerholm et al., 2019; Fagerholm et al., 2020). Even though approaches such as public participation geographic information systems use facilitators and data collection is performed in-situ in local languages, the conceptualisation of landscape as a function of language is mostly ignored. The results of analysing the contributions to *Window Expeditions* hints at potential insights into a plethora of cultural ecosystem services (e.g. recreation, identity or tranquillity) and combined with the multilingual nature of the generated corpus as well as the focus on everyday lived landscapes, could help identify important gaps in contemporary work.

Secondly, identifying people's sentiments towards landscapes has been identified as an important part of landscape perception research (Koblet and Purves, 2020; Huai and Van de Voorde, 2022). However, corpora used to train sentiment analysis algorithms are commonly based on the general meanings of words and are thus not domain specific (Chesnokova and Purves, 2018; Koblet and Purves, 2020). The results show the generated corpus is domain specific and a larger annotated corpus could potentially complement more generic sentiment analysis approaches.

Thirdly, indirect perception theories and in particular affordances have been identified as potentially powerful complementary approaches to analysing landscapes (Heft, 2010; Raymond et al., 2017). Moving away from predefined categories of sensory experiences and cultural ecosystem services towards a more affordance focused approach may allow for the collection of more comparable data sets across cultures and languages. In accordance with the notion of ambient affordance arrays (cf. Gibson, 1986) containing every possibly conceivable affordance and fully surrounding individuals at all times, capturing and exploring these ambient affordance arrays may provide novel insight into emergent intangible dimensions overlooked by traditional methods of exploring cultural ecosystem services. One possible approach to building such ambient affordance arrays is capturing not only salient landscape elements, but all perceived dimensions of a specific landscape from a large variety of data sources and participants, leaving room for future additions as they are perceived and communicated. This would allow for various landscapes to be compared through their respective ambient affordance arrays whilst remaining dynamic and allowing for new emergent conceptualisations by not predefining categories such as in the Landscape Character Assessment (Tudor, 2014) or Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005).

Lastly, in-situ data of how people perceive landscapes are important for landscape perception research, especially when investigating sensory experiences or intangible dimensions (cf. Wartmann et al., 2018; Bubalo et al., 2019; Koblet and Purves, 2020; Fagerholm et al., 2020). However, collecting data in the field is costly and can take a lot of time. These shortcomings have been circumnavigated with virtual representations of study areas, which is common in studies on spatial cognition and navigation (cf. Coutrot et al., 2018a). With the possibility of increasingly realistic virtual environments, landscape perception research could potentially overcome some of the contemporary issues of conducting research in virtual environments and shift towards virtual environments as a proxy of real landscapes. A few studies have emerged showing virtual environments can be believable and potentially target underrepresented demographics (Swetnam et al., 2017; Chandler et al., 2022). I propose further inquiries into performing landscape perception research in virtual environments, especially seeing the scalability and modularity of virtual environments.

9.2 Conclusion

In this thesis I set out to explore the potential of a gamified active crowdsourcing platform in generating rich in-situ natural language descriptions of everyday lived landscapes and what perceptual and experiential dimensions the contributed descriptions capture. The need for complementing landscape perception research, commonly focusing on particularly aesthetic or idealised landscapes, with inquiries into everyday lived landscapes has intensified with the global Covid-19 pandemic, where many individuals were confronted with reduced mobility through lockdowns and self-isolation. By building on lessons learnt from developing and implementing two gamified crowdsourcing applications and eliciting data and feature requirements using scientific frameworks, I developed, implemented and maintained a playful application called *Window Expeditions*. In *Window Expeditions*, interested participants could upload written descriptions of their immediate surroundings in English, German and French. Through targeted promotional efforts, the application successfully generated over 600 written accounts of how participants experienced and perceived their everyday landscapes. I then processed and analysed the contributed natural language descriptions with various computational approaches, complemented with human annotation and qualitative inspection, to identify salient biophysical elements, noteworthy sensory experiences and perceived cultural ecosystem services.

Initial exploration of the generated data through natural language processing, computational linguistics, multilingual comparisons and spatial analyses showed that the generated data were rich in landscape specific features and that participants commonly describe urban and residential landscapes. The presented work finds various commonalities as well as noticeable differences when comparing the frequencies of terms used to describe landscapes in English and German within the multilingual *Window Expeditions* corpus. Commonalities include salient features of everyday lived landscapes reflected in frequently used terms such as "*tree / Baum*", "*house / Haus*", "*garden / Garten*", and "*street / Strasse*". Differences can primarily be attributed to the underlying natural language processing algorithms which are accompanied by varying levels of accuracy as a function of language.

In addition, this work compares the *Window Expeditions* corpus to the British National Corpus (BNC) of general English language as well as a collection of representative landscape image descriptions (Geograph). Terms which were significantly overrepresented in the actively crowdsourced *Window Expeditions* dataset (e.g. "*tree*", "*window*", "*house*", "*bird*", "*building*") were identified. Exploring the identified terms strengths the argument that the actively crowdsourced corpus is indeed domain and genre specific (in-situ first person natural language descriptions of everyday lived landscapes).

Further, through an iterative annotation approach, a number of biophysical elements and categories (e.g. *vegetation*, *built environment*, *weather/atmosphere*, etc.), sensory experiences (e.g. *sight*, *sound*, *smell/taste*, *touch/feel*) and cultural ecosystem services (e.g. *recreation*, *tranquillity*, *heritage*, etc.) were identified and the links between these were investigated. This thesis finds visual and auditory sensory experiences to be referred to more frequently in the contributed descriptions compared to olfactory and haptic sensory experiences. In addition, the cultural ecosystem service of recreation was referred to notably more frequently than other intangible dimensions. These findings allow complementary insights into how everyday lived landscapes are perceived and valued, and thus have important implications for policy and decision making processes.

Finally, the generated, annotated and curated corpus of English natural language contributions to *Window Expeditions* was used as a gold standard set of high quality landscape relevant documents, which were subsequently used in a novel computational workflow. Using sentence-transformers landscape relevant documents in other collections were identified. The results show that having a human annotated landscape specific corpus and using sentence-transformers as well as cosine similarity calculations, similar documents can indeed be identified, opening the door for large-scale analyses from small-scale data collection efforts.

This work highlights language specific differences in what is described in everyday lived landscapes whilst revealing salient semantics about participants' immediate surroundings. The results provide further evidence supporting the notion that language and landscape are deeply intertwined and strengthens the call for individual demographic and socio-cultural information to be taken into account when exploring how landscapes are perceived. Landscapes are shared and perceptions thereof subjective. This thesis advocates the inclusion of more participatory data from a diverse audience to be included in future landscape perception research, especially when guiding policy and decision making processes.

Landscapes invoke various emotions, from fear and joy to longing and disgust. Landscapes are where the hustle and bustle of everyday life plays out, with pockets of tranquil refuge found in the most unseeming of places such as gardens and balconies. This thesis goes to show that one does not have to seek the wide blue yonder in search of idealised landscapes of particular aesthetic appeal to explore how landscapes are perceived. Merely venturing into the familiar everyday lived landscapes available at our doorsteps results in unique sensory experiences and invokes various emotions, sometimes unique to the perceiving individual, sometimes shared within a broader community. Barbara Bender was right to prioritise the ideas of artists and poets when asked to describe landscapes (Bender, 2006), as these are masters of conjuring vivid imaginations and fantastic scenes, captivating humans and sparking their interest. However, as this thesis has shown, anthropologists, geographers, linguists and computer scientists can provide unprecedented insights into how the large variety of landscapes found on earth are perceived, valued and appreciated, especially when working interdisciplinarily. As such, it is time we truly accept that one landscape is not better or worse than another and that a single academic discipline can never fully understand how we perceive landscapes. We must transcend valuating landscapes as well as individuals and forefront landscapes as dynamic entities deeply rooted in language and culture to pave the way for future research as well as policy and decision making.

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Colophon

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Declaration

I hereby declare that this thesis (titled: "Capturing Perceived Everyday Lived Landscapes through Gamification and Active Crowdsourcing") has been composed by myself autonomously and that no means other than those declared were used.

Zurich, November, 2022

MBär

Manuel F. Bär