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The AUC Undergraduate Journal of Liberal Arts and Sciences is a biannual, interdisciplinary publication showcasing outstanding undergraduate academic papers. The Journal aims to demonstrate the strength of undergraduate scholarship at AUC, to reflect the intellectual diversity of its academic programme, to encourage best research and writing practices, to facilitate collaboration between students and faculty across the curriculum, and to provide students with opportunities to gain experience in academic reviewing, editing and publishing.

FOREWORD

Each year, the *AUC Undergraduate Journal of Liberal Arts and Sciences* devotes one issue to showcasing AUC Capstone projects. The Capstone project is a thesis completed in the final year of study on a topic developed by the student which requires both independent research and substantive engagement with existing scholarship in his or her field. This issue's focus on Capstone theses reflects the mission and values of AUC in the sense that the following articles contain outstanding undergraduate student work, and are also representative of a much larger body of student work - across the Sciences, Social Sciences and Humanities – that develops expertise in a diverse range of disciplinary fields. AUC's focus on excellence in teaching and learning aims to provide students with the skills and experiences needed to unlock the potential of their critical and creative thinking.

In this issue we profile four Capstone theses selected by the AUC Capstone Awards Committee for the awards of 'Thesis of Distinction' and 'Thesis of Highest Distinction'. Together, these essays provide a sense of the breadth of student research as well as the originality and ambitions of our student writers. Although the essays cover a lot of cultural and scientific ground and may on the surface appear eclectic in their intellectual projects, there is one unifying theme: transformation. From the study of new augmented-reality museum apps and fresh readings of women's roles in literature, to creative reimaginings of collaborative workspace in London's Kings Cross and new discoveries in pharmaceutical drug development, these projects all succeed in addressing the rapid and profound transformations occurring around us.

Prof. Dr. Marijk van der Wende,
Dean

Dr. Rebecca Lindner,
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The Ideal Fit: Features Affecting the Binding Affinity to the H_1 Receptor and Novel H_1 Ligand Identification

Kim van der Weijde

ABSTRACT

Since the attainment of the crystal structure of the histamine H1 receptor, structure based research in the field of drug discovery has flourished. By identifying features of both active ligands and the receptor protein that are crucial for active binding, increasingly specific screenings and discoveries have been able to take place. In this study, a Quantitative Structure Activity Relationship approach, or QSAR approach is taken to identify important features that affect the binding affinity of active histamine ligands. Known active H_1R ligands were initially clustered into groups by structural similarity, docked in the H_1R receptor by PLANTS, and scored through both IFP and PLANTS based scoring. The interaction points of these complexes were then generated using GRID, from which the data subsequently underwent data mining using WEKA. Results identified multiple features that are significantly influential on binding affinity, including ligands which possess hydrophobic, aromatic, and hydrogen accepting or donating moieties. Three specific characteristics recognized by these studies were then used to identify novel ligands with relatively high affinity binding potential by the filtering of a known chemical database by a combination of FlexX docking and scoring. The most promising ligands were finally used to construct two models which entail the characteristics and structure that we predict will provide an ideal binding mechanism, and therefore relatively high affinity binding, with the H_1R receptor. These models allow us to estimate the specific pKi of our novel ligands as well as other H_1R ligands based on the presence our predicted essential characteristics. We additionally discuss the implications of our results and the overall conclusions that we drew based on the effectiveness and interpretation of the processes used.

1. INTRODUCTION

The histamine receptor, a member of the G-protein coupled receptor family, has been the target of much recent attention since the attainment of its crystal structure in 2011 (1). The histamine receptor functions as a crucial regulator of physiological activities, especially that of allergy and inflammation, by actions of histamine on one of four subtypes of the receptor: H_1, H_2, H_3, and H_4 (1). The H_1 receptor in particular, the focus of this study, has been found in the airway, intestines, vascular muscle, and brain (2). Access to the crystal structure of the H_1 receptor has stimulated structure based research in ligand discovery, allowing for the development of increasingly specific hits, formatted by the analyses of interactions within the binding pocket (1). The increased knowledge of structure based interactions is crucial not only for our understanding of ligand positioning, but for the improvement of anti-histamine drug development, which still faces challenges with unwanted side effects (3; 4).

The field of drug discovery uses a combination of methods for the ultimate identification of novel ligands including high throughput screening, structure based virtual screening, and fragment based drug discovery. All methods carry their own advantages, such as large quantity screening, optimal ligand selection, and the ability to build an idealized molecule based on features and increasing affinities, respectively (5; 6; 3). The processes of drug discovery are under the constant influence of scientific advancements, where discoveries such as the crystal structure of the H_1R receptor, allow for ever improving specificity, adaptations, and variations, in order to design or identify ligands that produce a desired interaction. Computational (medicinal) chemistry utilizes these methods to increase the efficiency of hit searches by optimizing inputs with specificity towards the binding pocket, resulting in increased active ligand discoveries. Known hits can then be used to identify common features that are necessary for the active binding of a ligand, and can be further extended as a predictive measure of the activity of a novel molecule; a process known as quantitative structure activity relationship (QSAR) (7). The important features of a ligand or ligand group are determined by implementing a set of parameters to the target, which can include "thermodynamic, electronic, geometric, and quantum mechanical descriptors" (7).

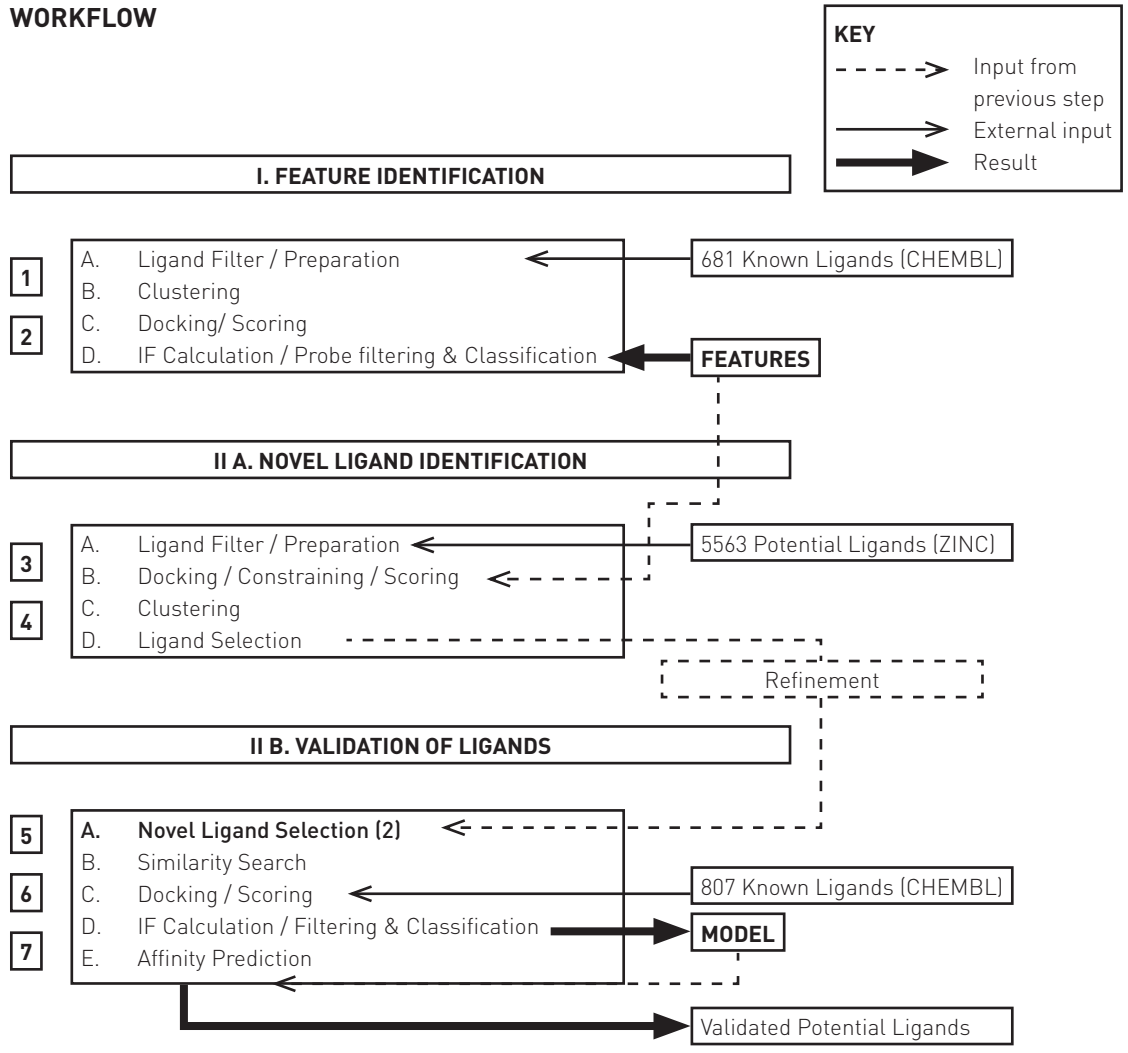
By aiming to relate the chemical structure and their alterations to properties important for biological activity, QSAR has been able to aid the optimization of lead compounds as well as predict the activities of novel or untested compounds (8). Classical QSAR models, however, which serve useful for analyzing a large amount of compounds and databases, have been met with numerous limitations. These limitations include, for example, limited physiochemical parameters, no demonstration of stereochemistry, a higher number of failures because of broad predictions, and no novel solutions or suggestions of compounds (9). Furthermore, because the process of developing QSAR models has become relatively user-friendly, models can be produced of which the function and limitations are not known (10). This effect is known as the "black box effect" (10). This lack of information was met with the development of 3D QSAR methods, which derive atom-based descriptors from the three-dimensional molecular structures, crystal structures, and relate them to target properties (8). The initial step towards 3D QSAR was Dynamic Lattice-Oriented Molecular Modeling System, which worked on a basis of vectors from the interaction fields correlated to bioactivity (8). Further modifications of this method led to the promising method of comparative molecular field analysis, or CoMFA, which considers the properties of ligands in their bioactive conformations in combination with GRID, which calculates molecular interaction fields, and partial least squares (PLS) techniques (11). Today there are numerous other 3D QSAR techniques which can be categorized by being ligand- or receptor-based, alignment dependent or independent, and linear or non-linear (8).

Of the most relevant advancements that have been made in terms of the H_1R receptor has been the identification of the crystal structure, which revealed the exact nomenclature of the receptor when docked with doxepin. This, in combination with numerous structure-activity relationship (SAR) approaches of H_1R inverse agonists, have allowed for the development of increasingly accurate pharmacophore models, which illuminate critical binding characteristics between H_1R and its ligands. Basic pharmacophore features include "two neighboring aromatic rings and a side chain with basic nitrogen" (12). The average distance between these two features is approximately three to four bonds (12). Antagonists also contain a protonated amine function, which makes an essential interaction with Aspartate in the H_1R pocket (12). Further SAR and homology studies have focused their pharmacophore models around a total of five features including: a hydrogen bond acceptor, an aromatic ring, a positively ionizable moiety, and two hydrophobic moieties (13).

The advancements that have been possible by the revealing of multiple GPCR crystal structures in combination with structure-activity based research have been rewarding. As summarized by Katritch et. al., 3D SAR studies are helping to turn "biochemical, biophysical, and computational inquiries into GPCR function and dynamics" (14). For example, one relevant study used 3D-QSAR techniques to gain better understanding of the fluctuation of residues that takes place in the binding pockets between inactive and active states of a protein. The shifting of Trp6.48, for example, acts a trigger that is initiated upon the interaction with an agonist, leading to the movement of helix VI. Understanding the importance of such a residue can be used to better optimize ligand design, and can direct the focus of researchers to crucial residue interactions in the protein. It was furthermore discovered that an inverse agonist stabilizes the inactive position of Trp6.48. (15) (16).

Also, in a recent study by Istyastono et. al., which aimed to better understand the selective binding mode of ligands to the H_4 receptor over the H_3 receptor through a 3D QSAR based study, it was revealed that clobenpropit, a known active H_4R ligand, can be altered so that it adopts specifically to one of two binding modes in the H_4R pocket (17). The binding affinity of ligands was shown to be related to both ligand size and conformation energy, which led to probes being able to link specific residues to H_4R specific binding modes (17). This was later validated by a site-directed mutagenesis study (18). Further gains in structure-activity knowledge, such as that gained in these examples, is what will ultimately reveal the complete picture of how receptors function, and will allow researchers to design ligands that are able to regulate their function to an individual's needs.

WORKFLOW



LITERATURE REVIEW

GPCRS

The histamine H_1 receptor belongs to the superfamily of G protein coupled receptors, or GPCRs, which is comprised of nearly 800 different human genes, making it one of the largest families in the entire human genome (19). The GPCR superfamily is built up of five families of proteins including glutamate, rhodopsin, adhesion, frizzled/taste2, and secretin, which are further broken down into various subgroups (14). The vastness of the GPCR superfamily can be visualized below in figure 1. All GPCRs consist of seven transmembrane alpha helices and act as signal transducers for ligands such as hormones, proteins, lipids, and pheromones, allowing for cell to cell communication and cellular response to numerous physiological and pathological processes (14) (20). The cellular response is stimulated by the binding of an external ligand to an activated GPCR, which is recognized by a G protein on the cytosolic side of the cell membrane. A second messenger system then modulates the activity of enzymes within the cell, stimulating a cascade which ultimately affects a cell's transcription of its DNA (21).

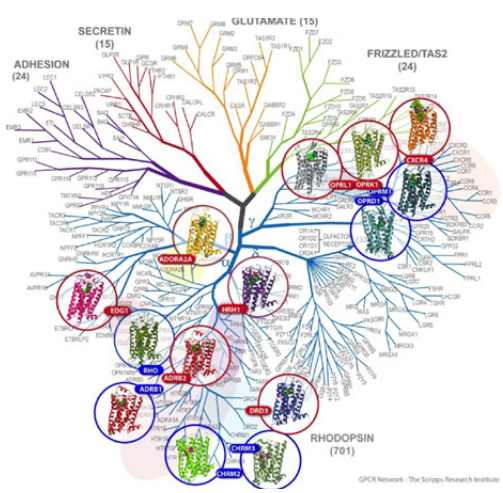


Figure 1 (22): *GPCR Family*

Overall, GPCRs show a great conservation in their overall physical structure and their signaling method through interaction with G-proteins (22) (21). GPCRs share the presence of seven transmembrane domains, three intracellular and intracellular loops, an amino-terminal extracellular domain, and an intra-cellular carboxyl terminus (23). However, their varying amino acid structures have led to a wide variety of functions within the superfamily, and overall, the GPCR superfamily shares a sequence identity of less than twenty percent in the transmembrane domain (14). While additional classification approaches have been based on physiological and structural features, GPCRs remain to be most commonly aligned by their sequence and classified according to the GRAFS system (24).

The histamine H_1 receptor in particular, which can be seen ins figure 2, is a member of the largest family of GPCRs, the rhodopsin family. The rhodopsin family commonly shares the NSxxNPxxY motif in TM7, the DRY motif or D(E)-R-Y(F) at the border between TM3, and intra cellular loop (IL) 2 (24). The sequence alignment within the rhodopsin family has been reported at greater than 25% while its four main subgroups share more than 30% sequence identity (19). The most pronounced variations between subgroups, due to differences in sequence identity, include modifications in the extracellular loops, side chains, and the 7TM helical bundle in the form of kinks, bulges, and n-helices (14). These variations make the classification of the rhodopsin family into subgroups crucial, because the changes furthermore regulate the specifics of the binding pockets within the receptors, and therefore the repertoire of ligands (14). Minimum sequence identity further becomes important when considering the use of homology models, for example, as it has been reported that having 35 to 40 percent sequence identity is sufficient enough to execute an effective docking run (14).

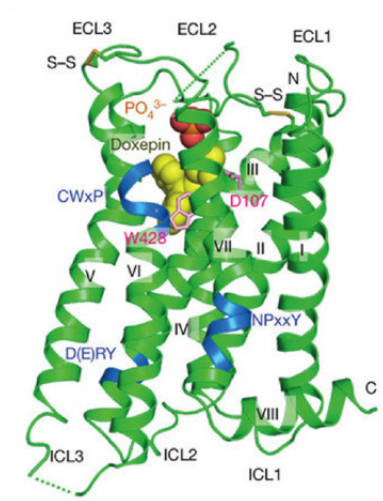


Figure 2 (25): *Histamine H1 Receptor*

HISTAMINE ANTAGONISM HISTORY

The history of histamine antagonists began in 1910 when researchers Dale and Laidlaw directly linked histamine to the physiological response brought on by allergies (26). Histamine, pictured in figure 3, a chemical messenger stored in mast cells and basophils, is released upon the stimulation by an immunologic or nonimmunologic trigger such as immunoglobulin E, cytokines, or mastoparan, through the process of degranulation (27). Once released, the H_1R receptor is responsible for inducing an allergic response, often characterized by redness, itching, and swelling (27). The histamine H_1 receptor naturally acts as a receptor for histamine in the body, and is commonly found in smooth muscle, fine blood vessels, and the brain (28). Interactions between H_1R and its amine histamine have been found to cause many unfavorable reactions in the body, mostly related to allergic and inflammatory reactions due to its interference with immune responses and the provocation of related physiological responses (28). H_1R has been found to be involved with asthma, low blood pressure, hypotension, tachycardia, flushing, headache, cutaneous itch, and nasal congestion (29). Based on the involvement of H_1R in such a large span of physiological reactions, the relevance of H_1R to the medical field becomes apparent.

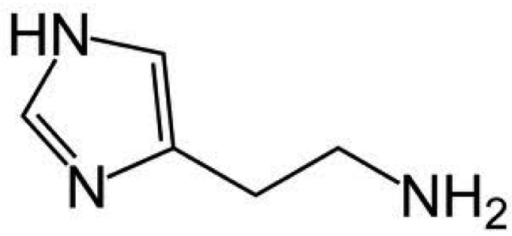


Figure 3: *Histamine*

The first antihistamine, thymoxidiethylamine, was synthesized in 1937 by creating compounds that resembled the histamine receptor's natural agonist histamine, in an attempt to block its natural mode of binding to the histamine receptor (30). As more was discovered about histamine and its receptors, novel antihistamines continued to be developed with increased efficacy through the early 1940's and 1950's. It was discovered by Ash and Schild in 1966 that there were also classes of the histamine receptors which were unaffected by the then current pharmaceuticals, leaving activities such as stimulation of gastric secretion, inhibition of uterus contraction and stimulation of isolated atria uninhibited (31). This discovery led to the classification of the H_1R receptor, which pharmaceuticals at the time were capable of inhibiting, in addition to another class of receptors which were up till then unaffected by antihistamines.

While initial research on antihistamines was done under the assumption that H_1R antagonists were limited to strictly inhibiting histamine interactions with receptors, it was later discovered that antihistamines are also capable of preventing the release of histamine by basophils and mast cells (32) (33). Furthermore, more recent research has proposed that anthistamines may also work by suppressing the actions of NFkB, which regulates the production of proinflammatory cytokines and adhesion molecules through interaction with specific genes (33). This research, although potentially influential on current antihistamine development, is still largely under investigation.

The first H_1R antagonists to be developed, known as first generation antagonists (see fig 4 for 2 representative members), encountered numerous pharmacological difficulties, however, despite their rapid advances. In general, first generation antagonists were known for having poor selectivity for the H_1R receptor and were able to bind with other GPCR receptors capable of binding biogenic amines, leading to antimuscarinic, anti-a-adrenergic, and antiserotonin effects (34) (32). Furthermore, their ability to penetrate the blood brain barrier and interact with histamine receptors at the central nervous system caused side effects such as drowsiness, sedation, fatigue, and impairment of cognitive function and memory (34) (25). Second generation antihistamines (figure 5), which first became available in the 1980's, offered highly selective H_1R receptor targeting and a large reduction of nervous system related symptoms (34). The improvement of second generation antihistamines lies in the addition of a carboxylic moiety and protonated amine, which reduces the drugs ability to cross the blood brain barrier and improves H_1R selectivity, as well as promotes active transport across the blood brain barrier out of the brain (25).

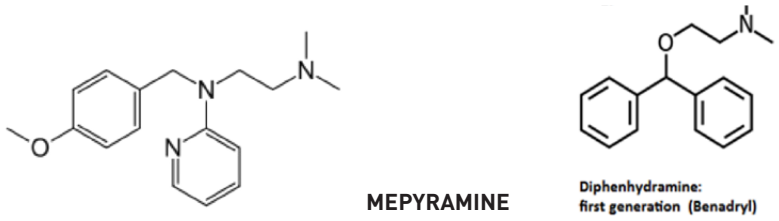
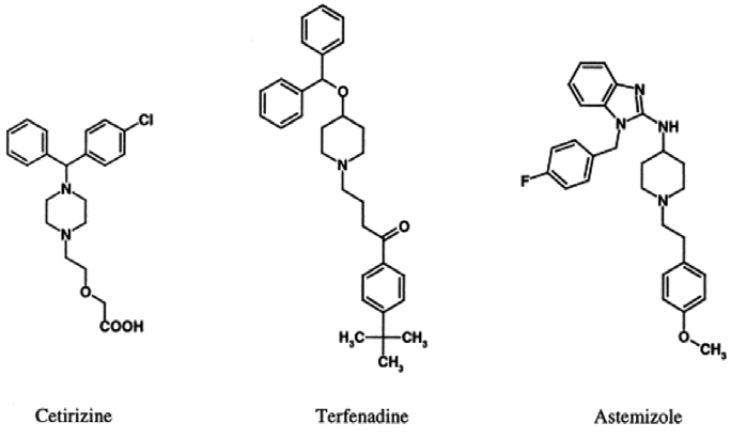


Figure 4: *First Generation Antihistamines*



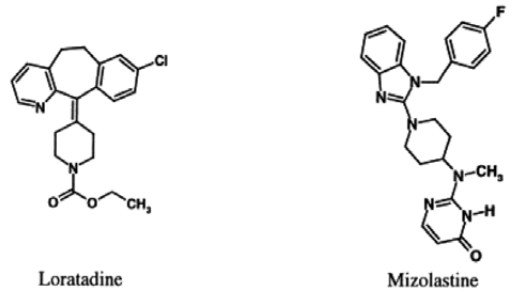


Figure 5: *Second Generation Antihistamines*

An important breakthrough for H_1R research was the first successful cloning of the bovine H_1R receptor in 1991, which allowed scientists to accurately analyze the structure-function reslationships of the receptor, it's relation to other histamine and GPCR receptors, and it's precise localization throughout the body (35). With access to the clone of the H_1 receptor, further studies were able to focus on and better specify the function and regulation of H_1R, as well as identify variations among forms of histamine receptors (35). Genes encoding the other histamine receptors have since also been cloned, allowing for the analysis of differences among histamine receptors 1, 2, 3, and 4. Overall, upon gaining the DNA clone of the H_1 receptor, researchers were able to approach the development of future antihistamines using structure-based design.

It was also discovered that the ligands that were being used as antihistamines act as inverse agonists, which means that they stabilize the receptor in an inactive conformation, reducing its basal activity, and presumably interfere with "molecular switches" in

GPCR activation (36) (25) (37). The concept of inverse agonism stems from the fact that GPCR proteins have the ability to become spontaneously active in the absence of its agonist (38). This better understanding of the H_1R antagonist mechanism plays an important role in drug discovery because it allows us a clearer understanding of how potential drugs work and therefore allows researchers to better tailor to specific drug needs. For example, ligands thought to have no intrinsic activity, but that actually inhibit spontaneous activity (38).

QSAR

Most recently, the study of GPCR's, including that of histamine receptors, has advanced to using quantitative structure-activity relationship studies, or QSAR. QSAR methods are used in drug design to correlate biological activity with physico-chemical properties, or to understand how structural changes affect biological activity (39) (40). These calculations are based on a set of similar structures, in which small changes are correlated with resulting biological activity (39). More specifically, QSAR studies develop models that first account for a given relationship between structure and activity, and then use this information to predict the activity of a novel chemical or ligand (40). QSAR studies are especially used in developing new drugs, as well as lead optimization. The use of QSAR in antihistamine research was largely enhanced by the obtainment of the bovine rhodopsin crystal structure by Palczewski et. al. in 2000, which can be seen in figure 6 (41). Being able to visualize the rhodopsin structure was very influential on GPCR research because it provided a three dimensional look at the receptor and validated and refined the previous GPCR models which had been generated based on experiments such as mutational studies. Valuable information such as ligand binding mechanisms, G-protein activation, and structural conservations were able to be visualized (42). Most significantly, the crystal structure of rhodopsin allowed for ideal homology modeling of the H_1R receptor, which is used for the prediction of ligand binding as well as virtual screening runs (43). The addition of other GPCR crystal structures, such as of the squid rhodopsin, ADRB2, and AA2AR have further contributed to the increased precision of homology models, as their structures can also be taken into account for specific domains or motifs (43).

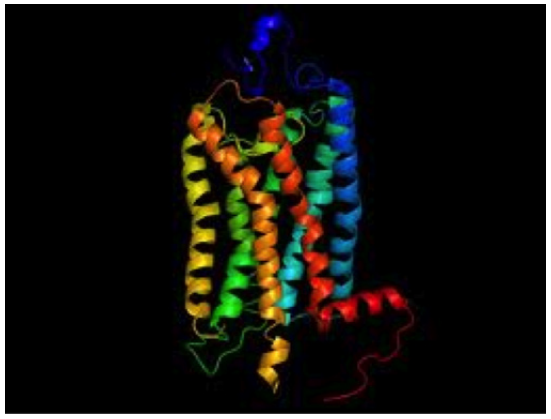


Figure 6 (41): *Rhodopsin Receptor*

Three-dimensional information is invaluable information for the discovery of novel ligands that overcome the shortcomings of prior H_1R therapeutics, as well as enhancing the overall pharmacological potential of H_1R antagonists. The largest milestone for H_1R research has been the report on the crystal structure of the human H_1R receptor co-crystallized with the ligand doxepin by Shimamura in 2011 (25). The crystal structure shows that H_1R resembles the aminergic and dopamine receptors more closely than rhodopsin, adenosine, and CXCR4 (25). Overall, the gain of information included the recognition of many conserved motifs compared to close GPCR family members, as well as unique features, such as a proline induced kink in the transmembrane segment (25). Moreover, researchers now have an actual snapshot of the binding mode that the ligand doxepin makes with the H_1 receptor, and can use this information in the search for novel ligands that have the potential to overcome current drawbacks presented by the antihistamine collection. Enhanced searches for novel H_1 histamine inhibitors have already begun, as has been illuminated, for example, by Singh et.al., who have developed a novel QSAR model with proven predictive methods for compelling compounds based on compounds expressing more lipophilic, less bulkier substituents, and their electrostatic potential (39).

Since the initial GPCR crystal structure has been released, a total of thirteen more have been added to the knowledge base, and have impacted research dramatically, especially in the field of structure based docking. This is evident in the number of novel active molecules as well as chemical scaffolds that have

been documented for GPCRs (44). Docking studies have taken advantage of the crystal structures and used them in combination with large molecule libraries to identify prospective novel ligands (44). Specifically in the case of H_1R, docking studies have overall documented hit rates of 73%, more than 10 new scaffolds, and a highest recorded affinity of 6nM (44).

In the light of these new advancements, and with many more expected to come in terms of crystal structures, QSAR models, and docking studies, the field of drug discovery for H_1R inverse agonists is hopeful. However, it is now the task to utilize the information that is available to gain a better understanding of critical interactions, affinity enhancing characteristics and structures, and effects on biological activity. The histamine family in general, but also specifically the H_1 receptor, play an important role in critical body processes as well as the causing of symptoms in many common ailments and conditions experienced by a large portion of the population. Furthermore, antihistamines account for one of the most prescribed medications worldwide, and although already intensely studied, there are still questions left unanswered, as well as advancements that need to be made (33).

METHODS: PROGRAMS USED

The process of docking allows for the prediction of a ligand's binding mode and the interactions that take place between it and its target receptor (45). The docking of ligands was completed with the program PLANTS, designed by joint effort of Universitat Konstanz and Universite Libre de Bruxelles, which predicts the local minimal energy conformations of each ligand in respect to the binding pocket of the receptor (46). The binding poses are produced in consideration of flexible hydroxyl groups and ligand positioning, which are manipulated by an algorithm within the allotted space of the binding site (46). PLANTS can be used to distinguish biologically active from inactive components (46).

Two scoring processes were used to help determine the most idealized pose of the twenty-five produced by PLANTS docking: PLANTS and IFP. PLANTS-based scoring is based on the calculation of a ligands binding energy, while IFP takes into account a ligands binding mode (46; 47). The PLANTS scoring function is based on two previously designed scoring methods (PLP and ChemScore) which include, for example, calculating the steric clashes and the hydrogen bond interactions between the ligand and receptor protein (46). Negative scoring indicates better protein-ligand complementarities (46). IFP scoring, or interaction fingerprint scoring, translates the binding mode of a reference ligand into a bit string, and then compares it to the bit string of the ligand of interest (47). The bit string is calculated by assigning residues possessing specific interactions with a score of 1, and those residues without the given interaction a score of 0 (47). The two bit strings are then compared for similar binding mode interactions, and given corresponding scores (47). Scores increasingly close to 1 indicate a stronger similarity with the reference ligand (47).

The most idealized poses of each ligand were clustered into groups, and subsequently screened by GRID in order to determine the interaction energies across different points of the ligand. GRID positions a three dimensional framework around a ligand or protein, in which selected probes are moved across grid points to determine the energy of interaction created between the ligand and the probe, resulting in an interaction energy for every grid point (48). Probes carry the potential to form specific interactions such as hydrophobic interactions, hydrogen bond donors, hydrogen bond acceptors, and aromaticity among others (48). High interaction energies with probes indicate areas that would also interact strongly in binding (48).

WEKA, a data mining process designed by the University of WAIKATO, was used to identify the most important features for interaction of the ligand within the binding pocket (49). WEKA uses various algorithms to find patterns and consistencies in data in order to extract the most useful data (49). The initial step performed in WEKA utilizes a preprocess filter, which screens GRID results to determine specific probe points where interactions are predicted to be crucial (49). The second process carried out in WEKA uses classifiers to determine the accuracy of the predictive model of WEKA, the pKi of the ligand or ligand group, the weight of influence that each probe carries, as well as the correlation effect that the probe shows on a ligand's binding (49). The results of the second WEKA run can be interpreted both visually, using a plot, as well as numerically, through the presentation of the correlation coefficient, the mean error, the pKi, as well as the correlation and weight of each identified probe (49).

FlexX docking, provided by the program LeadIT, was used in the second phase of the study to identify novel ligands which encompassed the specific features that we had identified as crucial for high affinity binding. FlexX is a docking method which uses incremental approach to construct ligands into the active site (50). It does so by implementing a triangle and line algorithm, which places fragments according to their simultaneous interactions with the receptor (51). The triangle algorithm supports three interactions between the protein and ligand whereas the line algorithm places ligands making two interactions (51). The program, which docks flexible ligands, also allows for the implementation of pharmacophore constraints including both interaction constraints and spatial constraints (50), essential for our study. FlexX combines multiple techniques for its docking application, including using pose clustering to select the base fragment, and the use of the greedy construction method to build upon that fragment. Scoring is done in accordance to the protein–ligand interactions (50).

METHODS

PHASE I: FEATURE IDENTIFICATION

Step 1 consisted of the selection and preparation of the initial ligands, clustering them according to their structures, as well as obtaining their overall docking scores. The 681 ligands that were selected for the project in step 1, which had been previously annotated and checked for reliability based on the original publications, were chosen from the CHEMBL database following based on their affinity for the H_1 receptor (52).

The ligands were initially prepared for docking by the use of the protocol CXCALC, which first protonated the molecules at a pH of 7.4, and then incorporated the explicit hydrogen atoms, revealing the most probable protonation state of the molecules in the given environment (53). CORINA converted files from an MDL Structure Data File format into the three dimensional SYBYL Mol2 file type (53). Ligands were subsequently entered into the Molecular Operating Environment (MOE), where MACCS fingerprints were then calculated in order to cluster the ligands based on similar structural characteristics (54). Clusters were formed on the basis of similarity and overlap, which were at first filtered at strict levels, those having high similarity and high overlap, and subsequently lowered in equal amounts to allow for less constricted group formation.

The ligand clusters were docked using PLANTS to generate twenty-five poses of each ligand within the receptor pocket of the histamine receptor. These ligands were docked within the crystal structure of the H_1 receptor with the use of Doxepin as a reference ligand. A filter was then placed on the ligands, requiring ligands to possess a crucial interaction with the aspartate residue in the protein pocket at position 42 of the sequence. This interaction has been deemed a necessary requirement for effective active binding of a histamine ligand to the H_1R receptor as well as for other bioaminergic receptors (55). By means of visual inspection and PLANTS and IFP based scoring, the best pose of each ligand was determined. The visual inspection was based on the ligands overlay and physical similarity to Doxepin, as well as expected clashes and interactions with residues in the binding pocket.

Step two of the feature identification process included the actual identification of the interaction fields between the ligands and receptor and

concentrating the field into specific probe points representing essential interaction points. An initial run of all remaining clusters through the GRID software produced configuration files that were used to determine the usable minimum and maximum x, y, and z coordinates of the grid box surrounding the ligand (48). Only a hydrophobic probe was used for this analysis, at a distance of one probe per angstrom and extending 5 angstrom beyond the ligand. The minimum and maximum points that were produced from the analysis, based on where the hydrophobic probe made interactions with the ligand, determined the minimal and maximal sizes of the GRID box for the second GRID run. This was done to ensure that various boxes could be accurately overlain in order to compare the various interaction fields of the ligands within each cluster.

A second GRID run was then carried out to acquire the molecular interaction fields representing regions of high interaction of each cluster group. Each run used six probes to map a field within the minimum and maximum coordinate points that were defined in the first run. The probes, a hydrophobic probe, an sp2 CH aromatic probe, an sp3 amine NH cation, a neutral NH amide, an sp2 carbonyl oxygen, and an sp2 carboxyl oxygen, were set at an increment of 2 probes per angstrom. To remove unnecessary and redundant data, the results of the GRID run were then filtered by an in house program which ran a statistical analysis to include only the probes that had an absolute z-score greater than one and at least an absolute Pearson correlation coefficient of 0.3 with the affinity.

The data produced by GRID indicated the fields of interaction of the ligands (48). In order to condense the fields into specific points that correlate with specific interaction attributes of the binding pocket, the data mining program WEKA was used to filter out probes based on the selected attributes of best fit, genetic search, greedy stepwise search, and an exhaustive search (56). Data was minimized to contain between four and six probes, with four varying searches performed per cluster. The first two runs allowed for the completion of the genetic and best fit filters, followed by an exhaustive search and then greedy stepwise if necessary, while the third and fourth runs initially used genetic and best fit searches, although only to a partial extent, in order to allow for the combined use of other search filters. This reduced the data set from one that contained thousands of interaction coordinates per cluster, to the most significant five.

Data from the WEKA filtering process was then classified through the implementation of specific functions including multilayer perception, linear regression, and support vector machine (56). The resulting correlation coefficient and mean absolute error were used to determine the most efficient run of the initial WEKA process and the model's predictability. The remaining five probes of each cluster were each represented by an equation that presented the coordinates, correlation, and the weight of influence that each probe exerted on the overall affinity (56). The visualizations of these results, which determined the relationship between the predicted probe pKi to the actual pKi, or affinity, were represented by a plot. The linear correlation that this produced represents that accuracy of the models prediction. The data that was produced through WEKA gave the overall results of the weight of influence that each probe carries on overall binding affinity, the correlation of the relationship of the feature and the resulting binding affinity, and the overall accuracy of the prediction of the model created (56). This data, especially once the chosen probe points are visualized, is what identifies the most significant probe coordinates as well as their influence on affinity.

The final step in determining essential features, which related the WEKA data to actual ligand and binding pocket residues, was the visualization of probe coordinates in MOE alongside ligands of the cluster (at a one at a time basis), as well as the binding pocket. The visualized probes could then be visually correlated to residues within the binding pocket as well as to where on the ligand the residues likely interacted. A positively correlating probe, which was marked as green, identified where and what type of residue was favorable, while a negatively correlating probe, marked in red, indicated where a specific type of residue would not be favorable to binding affinity. It was the visualization of the probes against the ligand docked within the binding pocket that allowed for the development of a conclusion as to what residues are most influential on binding affinity.

PHASE IIA: NOVEL LIGAND IDENTIFICATION

In step three, potential H_1R ligands were selected from the ZINC database and clustered according to structure, and then docked, scored, and narrowed down by FlexX based on the features identified in step two. An initial database of chemical compounds was selected from the ZINC database by filtering ligands based on having common characteristics of known histamine ligands. These included having a molecular weight between 200-500 K, a logP between 1 and 5, between 4 and 7 rotatable bonds, between 1 and 3 hydrogen donors, and having between 0 and 4 hydrogen acceptors.

The resulting ligands were initially prepared for docking by the use of the protocol CXCALC, as in the previous section, which first protonated the molecules at a pH of 7.4, and then added the explicit hydrogen atoms, representing the most probable state of the molecules in the given physiological environment (53). Both groups of ligands were then entered into the Molecular Operating Environment (MOE), where MACCS fingerprints were then calculated in order to cluster the ligands based on similar structural characteristics (54). Clusters were formed on the basis of similarity and overlap, which were at first filtered at strict levels, those having high similarity and high overlap, and subsequently lowered in equal amounts to allow for less constricted group formation. The molecules were then docked and scored by FlexX docking in two separate runs. Both runs used were conducted in the H_1R pocket using doxepin as a reference ligand, and allowed for the generation of 25 best conformations. The features identified as essential for relatively high affinity binding were used as a filter for identifying novel ligands we predicted would have relatively high affinity binding for the histamine H_1 receptor. The initial run docked the molecules limited by only by a D3.32 restriction, which made it an essential feature for ligands to interact with D3.32. The second run incorporated both the D3.32 restriction as well as a pharmacophore feature restriction requiring an interaction with either Y3.33 or N6.48, both features which we previously identified as significantly affecting binding affinity.

In step four, which is applied over both phase IIa and IIb, the most likely high affinity binding ligands are selected as potential H_1R novel ligands based on scoring and visual inspection. The results from our docking studies were narrowed down by selecting for unique entries based on having the best top total score as provided by FlexX scoring.

Each cluster was then visually inspected within the H_1 receptor pocket in MOE, as well as analyzed based on FlexX scoring to determine the best representative ligand of each cluster. Three FlexX scores were now considered in the comparison, total docking score, contribution of the matched interacting groups, and contribution of the lipophilic contact area, while the visual inspection was based on the ligands overlay and physical fit within the pocket, as well as expected clashes and interactions with residues in the binding pocket.

Of the representative ligands selected from each cluster, the best five and six overall ligands were selected from both the unrestricted and restricted groups respectively. This analysis was also based on the three FlexX scores and visual inspection.

The final ligands of each group were then used to create a pharmacophore model to visualize which interactions where being made with the receptor and if these contained the restrictions implemented on the restricted group of ligands. Generation of the pharmacophore allowed for the comparison of binding modes, interactions, and overall layout of the ligand-receptor complex between the restricted and non-restricted ligand groups. The pharmacophore was implemented at a tolerance of 1.2 and a threshold of 57% for both groups. It was then possible to make comparisons between the two groups of ligands including the interactions they made within the pocket, physical structure and layout, as well as their general fit within the receptor pocket.

PHASE IIB: VALIDATION OF LIGANDS

From the two novel compound groups, which were comprised of the highest scoring H_1compounds of both restricted and unrestricted filtering, the two most ideal ligands were chosen to base a new similarity search on. These ligands were chosen based on their FlexX scores, their overall fit in the H_1R receptor, the strength of interactions made in the H_1R receptor, and their feasibility of development.

Step five consisted of performing a similarity search of the two selected ligands on a CHEMBL known H_1R database, which were then docked and scored using PLANTS.

MACCS fingerprints were calculated for each respective ligand in MOE, along with that of a database of 807 known H_1R ligands that were acquired from the CHEMBL database. These two ligands were then individually used to develop two similarity searches against the known H_1R ligand

database. It was essential that both resulting similar compound groups represented a broad pKi range of approximately twenty to forty compounds. Because the similarity searches were based on two compounds that we believed contained essential high affinity binding characteristics, the newly developed databases represented the ligands containing our predicted best pharmacophore feature features.

These two resulting databases were then docked by PLANTS in the H_1R receptor in order to determine the ligands most probable binding poses, as was done in phase I of our research. These ideal poses were used to develop a new QSAR model representing a set of H_1R ligands expected to contain the most ideal binding characteristics. This QSAR was normalized based on the initial hits that we acquired in the two representative ligand groups resulting from restricted and unrestricted filtering. The normalization process of the QSAR was done in the same manner as was done in phase I, which can be found in the methods section of phase I.

In step six the interaction fields of the models were identified through GRID and further concentrated and reduced to the six most crucial interaction probes for each group by WEKA. This resulted in an affinity predicting model.

The resulting QSAR model was run through two sequential GRID runs, which initially identified the minimal and maximum sizes of the ligand/protein complex through the use of a hydrophobic probe, which then allowed for the acquisition of the molecular interaction fields between the ligands and H_1R receptor. The GRID interaction probes that were used to identify the interaction field included a DRY (hydrophobic) probe, an N1 (H-bond acceptor) probe, and an O (H-bond donor) probe, at a distance increment of 2 probes per angstrom. Only probes with a standard deviation higher than one were included for the succeeding steps. The molecular interaction fields that were identified were then normalized to the same standards as the last developed QSAR model, which can be found in the phase I methods section.

The probe points that resulted from the normalized GRID runs for each respective reference ligand, which were transferred into .csv format, were then loaded into the WEKA data mining system. WEKA filtered the interaction field probe points based on the attribute filters of best fit, genetic search, greedy stepwise, and an exhaustive search. The data was to be minimized to four probe points per reference ligand, which was ultimately accomplished by setting a maximum probe allowance on a final best fit filter after all other attribute filters had been imposed. The resulting data was then run through multiple classifier functions including SMOreg, linear regression, and Gaussian processes, from which the model with the highest resulting correlation coefficient and lowest absolute error was chosen. All classifier runs were done without normalizing or standardizing the data.

Finally, in step seven, the produced models were tested for accuracy and used to validate the two novel ligands on which they were based.

Once the appropriate model was chosen for each respective ligand, the six selected probe points of each ligand were normalized by subtracting the mean value of that particular probe point and dividing the difference by the standard deviation. This was done for each of the 6 probe points of each ligand. Finally, this value was inserted into the formula of the respective model in order to calculate the pKi of each ligand.

To test the accuracy of our models on a larger scale, the same two models were applied to predict the pKi values of the known H_1R ligands originally used to construct the models, which were then compared to the actual pKi values of the ligands. A correlation coefficient (r^2) was then calculated based on these two variables, showing the strength of the models as a predictive tool. These results can be found in the scatter plots of both models.

RESULTS

PHASE I: FEATURE IDENTIFICATION

In step one, the initial clustering of the ligands using MACCS fingerprinting yielded twenty-four clusters of approximately twenty to forty ligands. Clear similarities of features within clusters were noticeable when shown in an overlapping manner in MOE for the clusters filtered under stricter circumstances, clusters one through eleven approximately. Later cluster numbers showed less structural similarity, due to the fact that clustering requirements were less strict. An example of this can be seen in figure 7, where Doxepin is represented in blue and the ligand being compared is in depicted in green. The most common overlapping features included specific binding residue locations, such as that of aromatic rings.

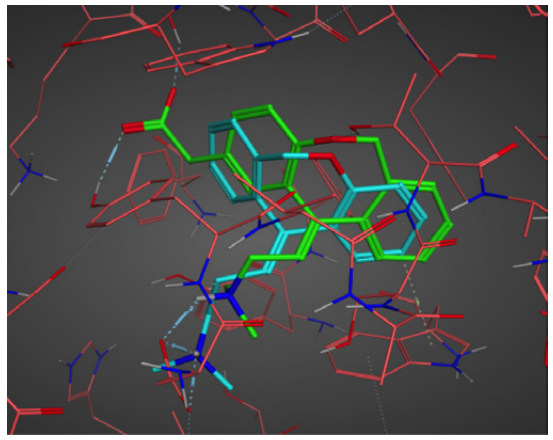


Figure 7: *Overlapping H1 ligand similarity comparison; Doxepin (green) as reference.*

The implementation of PLANTS based docking on the clusters produced twenty five poses per ligand. Filtering the results removed approximately one half of all poses, due to the absence of an interaction with the aspartate residue in the binding pocket. The optimum poses that were determined based on visual inspection and scoring functions were also saved within distinguished clusters. An example of a well matched ligand with the Doxepin ligand within the binding pocket can be seen in figure 8a. This can be compared with figure 8b, which exemplifies a poor pose of the same ligand. Doxepin can be identified as the blue molecule, while the docked ligand of comparison can be seen in green. The comparison between the visualization of the pose and the result of the scoring functions can be made through the use of table 1.

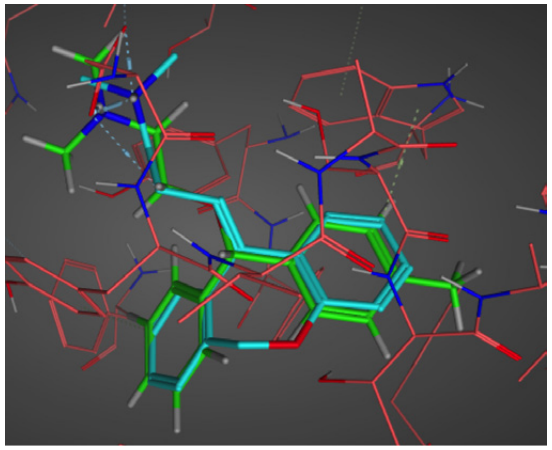


Figure 8A: *Well matched ligand to Doxepin (blue)*

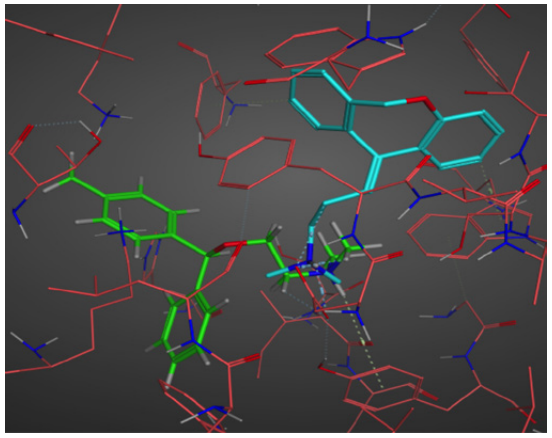


Figure 8B: *Poorly matched ligand with Doxepin (blue)*

Scoring Results Poor vs Good Pose			
Name	Figure	IFP	PLANTS
CHEMBL612084	3A	0.24	-54.05
CHEMBL612084	3B	0.96	-104.77

Table 1: *Pose Score Results (IFP and PLANTS)*

n step two, the interaction fields that were produced by GRID, based on the use of six interaction probes, revealed expected interaction fields in areas surrounding residues such as aromatic rings and polar bodies. An example of this can be pictured in figure 9, where the interaction field is especially noticeable around the aromatic rings, although other interaction fields can also be seen.

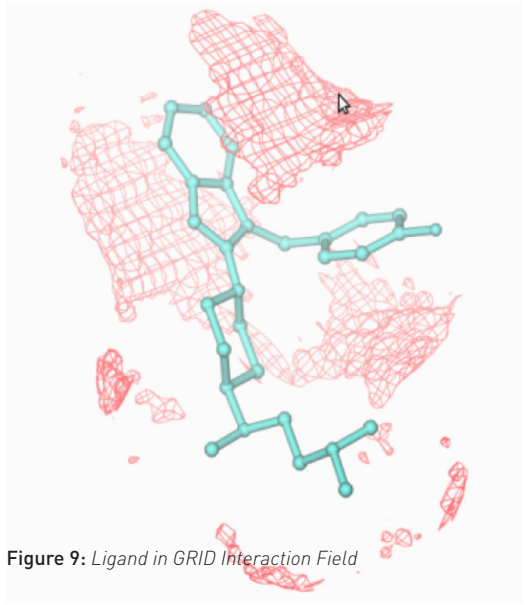


Figure 9: *Ligand in GRID Interaction Field*

WEKA processes revealed the most practical results towards answering the research question. The first run of WEKA revealed sets of approximately five probes that represented areas where interactions were determined to have the most effect on binding affinity. The second run of WEKA produced a table of information, shown here through the example of cluster 13 and 19 in table 2a and 2b, respectively. The resulting numerical WEKA data of our clusters proved to display good results, with correlation coefficients high, at .9856 and .9624, and low mean absolute error rates of .1328 and .2094. The correlation coefficient results, which show the accuracy of the models pKi prediction, can be visualized in figure 10a and 10b. Each point on the plot represents a ligand within a cluster. The clear linear relationship is indicative of a strong correlation coefficient, which matches numerical data.

Classifier model (full training set)
SVM reg weights (not support vectors): + 0.2128 * HYD. 53382 - 0.2651 * N1. 69190 - 0.2781 * N1. 62663 + 0.0935 * HYD. 50191 + overall pKi : 9.127 === Summary === 0.9856 Correlation coefficient

Table 2A: *WEKA Result Cluster 13*

Classifier model (full training set)
SVM reg weights (not support vectors): - 0.2498 * N1.. 47313 + 0.2603 * N1. 38536 - 0.24 * HYD. 22953 + 0.1117 * N1. 25495 - 0.0662 * HYD. 91307 + overall pKi: 5.8573 ====== Summary === 0.9624 Correlation coefficient

Table 2b: *WEKA Result Cluster 19*

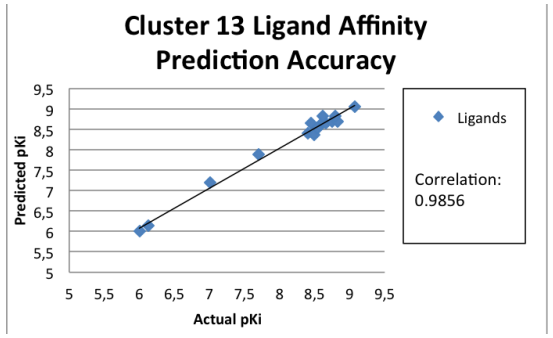


Figure 10A: *Accuracy of Cluster 13 Ligand Affinity Prediction*

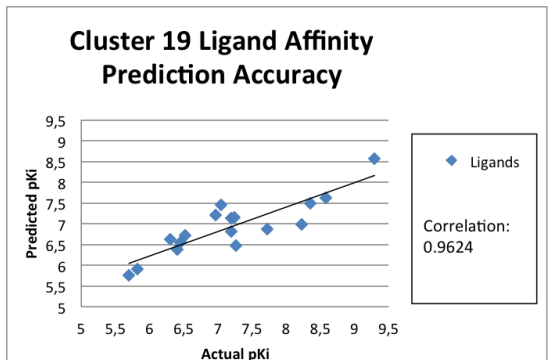


Figure 10B: *Accuracy of Cluster 19 Ligand Affinity Prediction*

The probes that were chosen as being the most influential on the binding affinity were visualized in MOE alongside each individual ligand within the binding pocket. By comparing the WEKA results in . csv format, which depicted each ligands specific interactions with each probe at a selected point, to the correlation and weights of the probe shown in table 2, it was determined that clusters thirteen and nineteen, docked with ligands four and eight respectively, represented the best example of how residues (both ligand and binding pocket residues) related to probe points. This can be visualized in figure 11a and 11b. Only critical residues of the binding pocket that are directly involved in ligand binding have been pictured.

Probe Key	
Probe	**Interaction Type**
Hyd	Hydrophobic
Aro	Aromatic (sp2)
Amn	Amine (sp3)
Cbn	Carbonyl O (sp2)
Color	
Green	Favorable
Red	Unfavorable

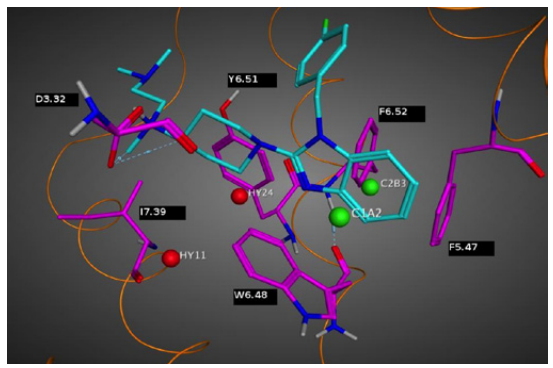


Figure 11A: *Cluster 13 Ligand with Probe Points*

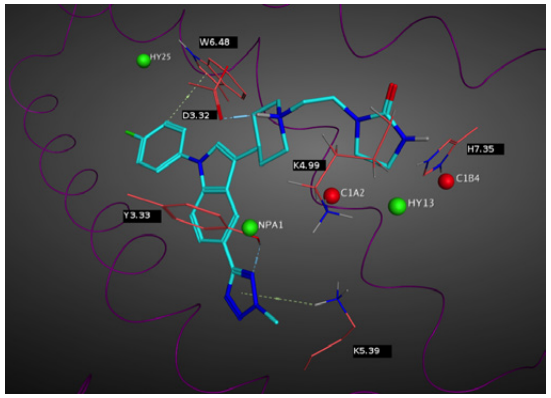


Figure 11B: *Cluster 19 Ligand with Probe Points*

Cluster 13 ligand four shows that it is not beneficial for the ligand to have a hydrophobic moiety in a low position when in the area of residue D3.32, as well as that it is beneficial to have an aromatic moiety in the pocket above residue W6.48 and resting besides residue F6.52 and F5.47.

Cluster 19 ligand eight shows that it is not beneficial for there to be an aromatic moiety between K4.99 and H7.35, but that it is beneficial for there to be two hydrophobic moieties, one near W6.48 and one ahead of residues K.499 and H7.35, and for there to be a hydrogen accepting residue on the ligand near binding pocket reside Y3.33.

PHASE IIA: NOVEL LIGAND IDENTIFICATION

In step three the initial filter of the CHEMBL database yielded 5563 potential compounds. Once these compounds were docked and scored by FlexX and unique entries were chosen based on best overall FlexX docking scores, two groups of 862 unrestricted molecules and 836 restricted molecules resulted. Clustering of these groups using MACCS fingerprints resulted in 17 and 16 cluster groups for the unrestricted and restricted groups respectively. There was a clear trend visible that the best scoring ligands were most commonly interacting with N6.48, followed by ligands interacting with Y3.33. Some high scoring ligands also made interactions with both, although not as frequently as those solely interacting with one of the two. There were also numerous ligands that interacted with the extracellular loop 2, ECL2, which was also identified as an important feature for good affinity binding, although it was not selected as one

of the essential features in the FlexX docking run. Explanations for this can be found in the discussion below.

In step four, after the initial selection of the best representative ligand for each cluster, the best 5 and 6 ligands of both the restricted and unrestricted docking were selected. These ligands can be found below in table 3, providing their molecular name and overall docking score, and can further be related to their overall structures in figure 12a and 12b.

	Unrestricted	FlexX Score	Restricted	FLEXX SCORE
Ligand 1	ZINC60700223	-33.30	ZINC57739463	-32.88
Ligand 2	ZINC79578378	-29.94	ZINC37864225	-31.87
Ligand 3	ZINC01678302	-27.06	ZINC01009357	-29.16
Ligand 4	ZINC37904020	-26.89	ZINC02193131	-28.85
Ligand 5	ZINC57740384	-26.42	ZINC37904164	-24.71
Ligand 6	-		ZINC60716204	-24.16

Table 3: *Best Ligands of Restricted and Unrestricted Docking*

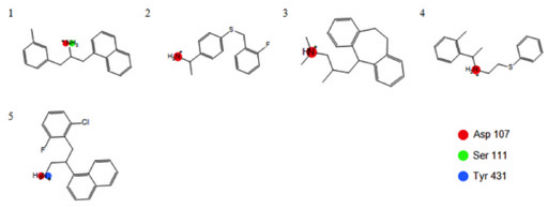


Figure 12A: *Best Ligands of Unrestricted Docking Group*

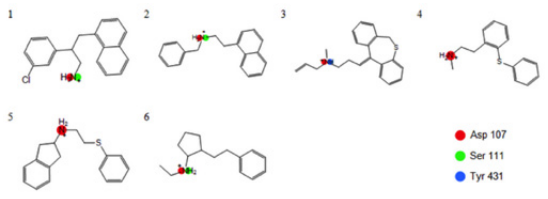


Figure 12B: *Best Ligands of Restricted Docking Group*

The pharmacophore models of each group of ligands, which represented our selected unrestricted and restricted ligands, revealed numerous similarities between groups. The group of unrestricted ligands, represented below by figure 13a, shows that all ligands interact with D3.32, shown by G1, 83% of ligands interact in a hydrophobic/aromatic manner with N6.48, shown by G2, and 67% interact in a hydrophobic/aromatic manner with Y3.33, shown by G6. Further common interactions include aromatic interactions with F6.52. Figure 13b, representing restricted ligands, shows that all of the entered ligands possess interactions with D3.32, represented by G1, 86% percent of ligands interact in a hydrophobic/aromatic manner with the N6.48, represented by G2, and that 71% of ligands make interactions near and likely with Y3.33, which is represented by G3. Further interactions that were common between ligands included aromatic interactions with F6.52 and hydrophobic interactions with T3.37 and W4.56.

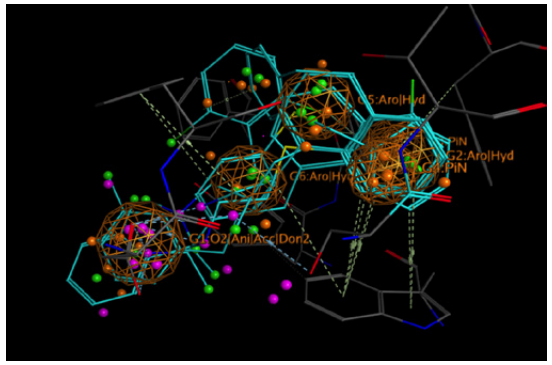


Figure 13A: *Pharmacophore of Unrestricted Ligands*

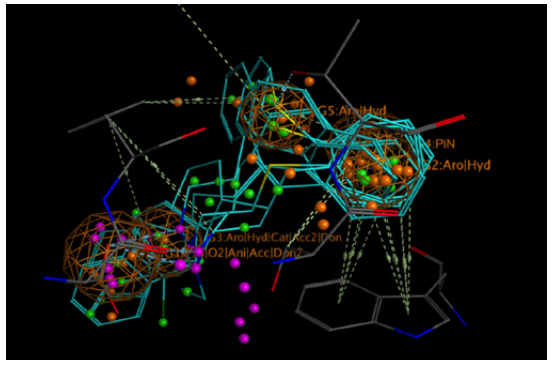


Figure 13B: *Pharmacophore of Restricted Ligands*

PHASE IIB: VALIDATION OF LIGANDS

The two ligands that were chosen to represent the best potential novel ligands were ZINC37864225 and ZINC01009357 (Fig. 14A and 14B). In step five, the similarity searches that were run on the known H1R database used a similarity of at least 50 for ZINC37864225 and 56 for ZINC01009357. This resulted in 23 similar compounds in reference to ZINC37864225 with a pKi range from 5.0 to 8.8, and 26 compounds in reference to ZINC01009357 with a pKi range of 7.3 to 9.8. The specifics of these compounds, including SMILE formulas, pKi values, and reference names, can be seen in Appendices A1 and A2 in supporting information.

Figure 14A: *ZINC37864225*

Figure 14B: *ZINC01009357*

In step six, once data was entered into WEKA, attribute filters revealed six probe points per reference ligand as having the highest correlation with the binding affinity. The clustering results, which we ultimately based on the so-called sequential minimal optimization (SMO) regression technique for both probe groups, revealed a relatively high correlation coefficient and low mean absolute error rate for ZINC01009357 of .934 and .1839. The ZINC37864225 model results showed a relatively high correlation coefficient of .8755, although the mean absolute error was quite high at .421. These models were created using a 10-fold cross validation, which uses 90% of the data as a training set, and 10% for testing. Results of the model can be seen in table 4A (ZINC37864225) and 4B (ZINC01009357). Visualization of the probe points in MOE can be visualized in figure 10A and 10B. A comparison of the ligand doxepin within the H1R pocket with the same probe points can be seen next to each image of the novel ligands.

SMOreg			
weights (not support vectors);			
-	0.2418	*	DRY-4165
-	0.4925	*	DRY-4166
+	0.137	*	DRY-4259
+	0.1029	*	DRY-4604
-	0.2572	*	DRY-5403
+	0.3152	*	DRY-6806
+	6.5668		

Number of kernel evaluations: 136 (99.426% cached)

Time taken to build model: 0.02 seconds

=== Cross-validation ===	
===Summary ===	
Correlation coefficent	0.8755
Mean absolute error	0.421

Table 4A: *WEKA results of ZINC37864225*

SMOreg			
weights (not support vectors);			
-	0.0819	*	DRY-3687
-	0.0959	*	DRY-3727
-	0.0825	*	DRY-5090
-	0.1435	*	DRY-7245
+	0.1363	*	O-7183
-	0.0827	*	O-7209
+	7.8569		
Number of kernel evaluations: 253 (99.787% cached)			
Time taken to build model: 0.04 seconds			
=== Cross-validation ===			
===Summary ===			
Correlation coefficent	0.934		
Mean absolute error	0.1839		

Table 4B: *WEKA results of ZINC01009357*

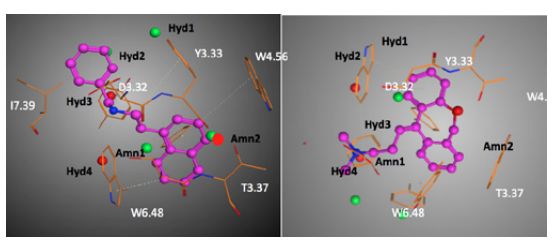


Figure 15A: *ZINC37864225 with Probe Points (left) Doxepin with Probe Points (right)*

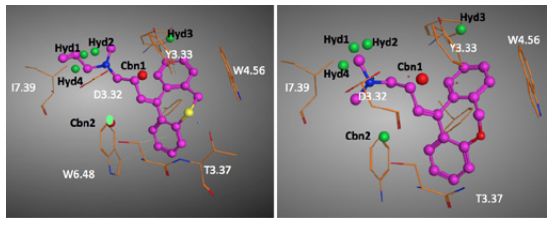


Figure 15B: *ZINC01009357 with Probe Points (left) Doxepin with Probe Points (right)*

The affinities of the ligands as calculated by their respective models were shown to have a pKi 6.75 for ZINC37864225 and 7.69 for ZINC01009357[1]. The affinities of the known H_1R ligands were then also recalculated using our models, and results were compared with their known pK_i values. The results, along with that of our two best ligands[2], were plotted on a scatter plot to visualize the accuracy of our model. This can be seen below in figure 16A and 16B. The coefficients of determination (r^2) show that our pKi predictions have been made with relatively high certainty, with the ZINC37864225 based model having a correlation coefficient of .923, while the ZINC01009357 based model had a correlation coefficient of .944.

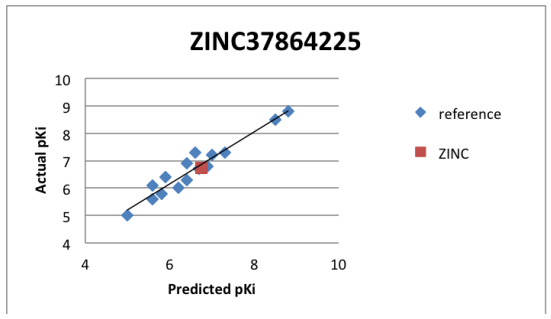


Figure 16A: *Accuracy of Predicted pKi for ZINC37864225*

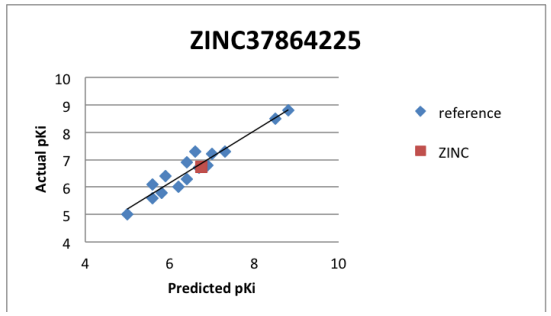


Figure 16B: *Accuracy of Predicted pKi for ZINC01009357*

[1] These pKi scores were not experimentally validated.

[2] The two novel ligands were plotted using their calculated pKi as both their predicted and actual pKi since their actual pKi is not known.

DISCUSSION

PHASE I: FEATURE IDENTIFICATION

The results that were visualized in MOE in step 1 of the workflow, in order to identify important binding features of the ligand, proved difficult to identify when looking at the pocket and ligand residues that were in the proximity of these areas. Cluster 13 and 19 contained the most explainable correlations between probe and respective residue or moiety, however, most clusters carried probes in positions that did not identify predicted or explainable interactions. Probes, identified in step 2 of the workflow, were expected to sit in areas that were in close proximity to interactions such as hydrophobic and aromatic binding sites, hydrogen donating and accepting residues, and other likely predictable areas. The probes that represented such unexpected areas would serve as good candidates for further research, in an attempt to understand their importance.

This further corresponds to that the ligands that had been clustered using high structural similarity and overlap according to MACCS fingerprinting, did not necessarily produce the most explainable features, which had been predicted. As clusters one through ten had the most similar structures within each cluster, it was expected that these would produce the best predictive models and that these would then correlate well with specific features related to binding affinity. Although clusters one through ten had good predictive models, it was not the case that they provided the most explainable features. It was not further investigated as to why the results developed in such a manner, however, this would also be an interesting future point of research.

Cluster 13 and 19, however, were found to have characteristics that well explained the positioning and correlation of the probe points. In figure 11a, representing cluster 13 with ligand 4, the hydrophobic moiety that most beneficially sits in a high position near residue D3.32, as expressed by probes HYD1 and HYD2, is likely explainable by the crucial interaction that takes place between the aspartate residue (residue D3.32), and the ligand (55). If the hydrophobic moiety were to sit in a low position, it would likely compromise the accessibility of the ligand to the aspartate residue, interfering with its binding. As for the aromatic residue that most beneficially sits in the pocket above residue W6.48 and resting besides residue F6.52 and F5.47, which is indicated by probes ARO1 and ARO2, is likely due to the hydrophobic interactions that take place between the ligand and those particular hydrophobic residues. A beneficial interaction probe near F6.52 was anticipated as it has been observed as a crucial interaction point in mutation studies such as that done by Bruysters et.al. and Wieland et. al. (57) (58). Replacement of F6.52 by an alanine moiety led to a loss of [3H]mepyramine binding (57) (58). Furthermore, although the measurement has not been taken between the ligand and residue W6.48, it appears as though it plays a role in binding.

In figure 11b, representing cluster 19 docked with ligand 8, there are also numerous explainable features. The negative correlation that is produced by the presence of having an aromatic ring in position between residues K4.99 and H7.35, as shown by probe ARO1 and ARO2, is expected considering that both residues are polar. This would thus favor a polar residue on the ligand as well. There is also a preferred hydrophobic area, visualized by probe HYD2, which sits immediately below the polar favoring area, which can be seen to be achieved by the lower half of the ring on the ligand. The hydrogen accepting residue that is favorable near position Y3.33, illustrated by the positively correlating sp3 amine probe AMN1, represents the hydrogen donating interaction between the ligand and residue K5.39, a lysine. Another favorable hydrophobic interaction near residue W6.48 of the pocket, exemplified by probe HYD2, can be predicted due to the hydrophobic interaction carried out between the two. A summary of the probe indications for both ligands can be seen in table 5.

Probe Indication Summary	
Cluster 13	**Figure**
Hydrophobic moiety: high position	Polarity -Between (K4.99, H7.35)
Aromatic Residue in pocket -Above: W6.48 -Besides: F6.52, F5.47	Hydrophobic residues -Ring interactions (near W6.48) - Ideal positioning (ahead of K4.99, H7.35)
	Hydrogen Accepting near Y3.33 (K5.39)

Table 5: *Summary of Probe Indications for Cluster 13 and Cluster 19*

PHASE IIA: NOVEL LIGAND IDENTIFICATION

The features that were ultimately chosen to act as a filter for novel ligands in step 2 of the workflow included an essential ionic interaction with D3.32, and an interaction between either W6.48 or Y3.33, however a simultaneous interaction was not necessary. These residues were chosen because an interaction with D3.32 is proven to be a crucial interaction point for all H1R ligands, while W6.48 and Y3.33 proved to be significant in our phase I study. Especially W6.48 was consistently shown to be an important moiety in H1R binding. This was further supported by the studies mentioned above by both Xu et. al. and Lebon et. al., which recognized W6.48 as a residue responsible for the stabilization of helix VI in an active or inactive conformation, depending on if the ligand acted as an agonist or inverse agonist (15) (16). Furthermore, in a mutation study done by Wieland et. al., it was shown that substituting an alanine for W6.48 resulted in a "dramatic" loss of affinity when binding with [3H]mepyramine (58). The replacement of W6.48 with a methionine or phenylalanine moiety also led to a loss of affinity, showing that W6.48 possesses specific characteristics needed for high affinity binding, not simply a hydrophobic or aromatic quality (58). Most importantly, however, was the discovery that W6.48 is likely an important binding point with antagonists within the H1R receptor (58).

While the most representative ligands that were selected for each cluster in step four did not overlap between restrictive and unrestricted groups, common features between both groups could be seen in terms of both structure and binding mode. This can be seen in figures 14A and 14B. For example, most ligands assumed a structure containing one or more ring scaffolds at one end of the ligand, and a nitrogen containing scaffold near the middle or opposite end of the ligand. Furthermore, numerous ligands attempted to extend into the pocket surrounded by N2.61, Y7.43, and D3.32. Similarities between ligands are to be expected, however, as a certain structure within the pocket and required interaction with D3.32 must be taken to allow for biological activity.

We focused on identifying beneficial pharmacophore features as our main method of screening our representative ligands. Focusing on pharmacophore features allowed us to distinguish types of interactions being made between the ligand and the receptor, and the strength of these interactions. We could therefore interpret which bonds played important roles in binding, and which ligands exemplified better binding based on the type and strength of the bonds made. While we also considered docking scores, these can also be influenced by the ligand itself in terms of its size and fit in the receptor, which can influence affinity predicting scores in an unwanted manner.

Similar interactions with the H1R receptor were made in both the restricted and unrestricted group, shown by figure 13A and 13B, which supports our prediction that interactions with W6.48 and Y3.33 result in the complexes with the highest affinity. Because of their similarity, we also believe that the representative ligands of both groups are all potentially high-affinity binding ligands that can be further researched in a laboratory setting.

In the pharmacophore representation of both restricted and unrestricted ligand groups, W6.48 came forth as the most common interaction with the H1 receptor, not considering the required D3.32, indicating that this interaction is regarded as being essential for an optimal fit. This was expected, as it came forth most prominently in phase 1 of our research as well. It is important to note, however, that the interactions between the restricted group and the W6.48 appear to be stronger than those between the ligands of the unrestricted group. Interactions with Y3.33 were also commonly reported in both groups, as well as interactions with F6.52. Both groups showed that ligands interacted with W6.48 in a strictly aromatic/hydrophobic manner, as expected, however interactions that took place near Y3.33 were shown to be of both aromatic/hydrophobic interactions as well as hydrogen acceptor/donor in the restricted group. It was predicted that interactions with Y3.33 would be as a hydrogen accepting moiety, due to its hydroxyl group, however, many scaffolds interacted in an hydrophobic/aromatic manner with its aromatic ring. It is unknown the difference in contribution to affinity this makes in comparison to hydrogen interactions, however, this would be an interesting topic to investigate in further studies. A further observation shows that the unrestricted group makes more interactions of lesser strength with other areas in the H1R pocket, while the restricted group makes stronger interactions with a fewer amount of areas in the pocket. This was expected, as the extra restriction placed on the restricted group likely allowed for less variation and therefore less chances to make additional interactions.

PHASE IIB: VALIDATION OF LIGANDS

The two molecules that were chosen as most ideal representations of our novel ligands in step four, which can be seen in figures 14A and 14B, were selected mostly because of the interactions that they made within the H1R receptor. ZINC37864225 made interactions with W4.56, W6.48, D3.32, and F6.52, while ZINC01009357 makes interactions with Y3.33, W6.48, D3.32, T3.37, and S3.36. ZINC01009357 makes more interactions with the residues that we predicted have a strong effect on binding affinity, and it was therefore likely that results based on this ligand would prove to be stronger than that of ZIN37864225. They were further selected for their ability to sit deep in the receptor pocket, especially near N2.61, and the overall feasibility of their development.

The probes that were ultimately chosen as having the most impact on binding affinity in step six of the workflow were rather predictable. These can be seen in figure 15A and 15B. Most probes in both models represent hydrophobic interactions, which are also commonly known pharmacophore features of the H1R receptor. The ZINC97864225 based model has two favorable hydrophobic interaction points and two unfavorable points. The two favorable hydrophobic points indicate that a hydrophobic moiety is beneficial between I7.39 and Y3.33, but a negatively correlating probe suggests that it should sit well above Y6.51. This is likely to ensure an interaction with D3.32. The positively correlating N1 probe, which represents a hydrogen accepting moiety, likely suggests an interaction with D3.32, while the negatively correlating N1 probe likely suggests that a hydrogen accepting moiety would disrupt the bond between the ligand and W4.56. Other hydrophobic moieties, including T3.37 and S3.36 are also present near this probe, further strengthening the argument that a hydrogen accepting moiety near the N1 probe would be unbeneficial. A hydrophobic moiety would likely act beneficially in this area. The ZINC01009357 based model indicates only one negatively correlating point near D3.32 and Y3.33, which represents a hydrogen donating moiety. This is likely unfavorable because it would disrupt the ligand's interaction with either D3.32 or Y3.33. The positive interaction points likely suggest that a hydrophobic moiety should stretch into the pocket near I7.39, and that a hydrophobic moiety should sit near F6.55. Last, the positively correlating O probe point near W6.48 could suggest that a hydrogen donating moiety on the ligand could place the ligand in a better position for hydrophobic interactions with Y3.33 or W4.56 by a repulsive interaction with the aromatic ring of W6.48. A summary of the probe indications can be seen in table 6.

Probe Indication Summary	
ZINC97864225	**ZINC01009357**
Hydrophobic moiety - Between I7.39, Y3.33 - Above: Y6.51	No H donating between D3.32, Y3.33
Hydrogen Accepting near D3.32	Hydrophobic residues -Into pocket near I7.39 - Near F6.55
No H accepting near W4.56, T3.37 -Hydrophobic moiety beneficial	Hydrogen donating near W6.48 - Repulsive → closer to Y3.33, W4.56

Table 6: *Summary of Probe Indications for ZINC97864225 and ZINC01009357*

The two models that were generated in WEKA predicted overall respectable pKi scores of 6.57 and 7.86 to ZINC97864225 and ZINC01009357 respectively when testing validity in step seven. Results obtained through WEKA can be seen in table 4A and 4B. The predicted pKi scores of the known H1R ligands that were calculated using our two models also showed very accurate values when compared to their actual pKi scores. This can be seen when looking at figure 15A and 15B, where a strong linear relationship between predicted and actual pKi values is shown. To quantify the accuracy of our models, a correlation coefficient was calculated of each relationship, which specified a correlation of .923 and .944 for both ZINC37864225 and ZINC01009357 based models respectively. Both of these values are very high, supporting our argument that our models contain essential characteristics that are significant for affinity prediction. The high correlation coefficients also validate the use of our models as accurate predictors of a ligands affinity for the H1R receptor. These models could not have been based on one model alone, as the applicability domain theory argues that QSAR models have questionable reliability because they are based on

limiting training sets (59). This leaves them restricted to being predictive of a limited chemical space in close proximity to the training compounds (59). An increased number of models are thus needed to remain within their "applicability domain" in order to remain reliable models (59).

The correlation coefficients that were calculated of the known H1R ligands also associated well with the correlation coefficients that were measured of our novel ligands in WEKA. The ZINC37864225 based model was calculated to have a correlation of .876 and a mean absolute error of .421, leaving it to be the poorer model of the two. The ZINC01009357 based model was calculated to have a high correlation of .934 and a mean absolute error of .1893. The accuracy of the two models, including correlation coefficients, can be seen in table 16A and 16B. That the correlation coefficient of known H1R ligands was calculated to be stronger for ZINC01009357 was thus expected by us, and would overall serve as a more accurate model than that of ZINC37864225. The reason that the ZINC01009357 based model is a more accurate predictor could be based on multiple effects. The most plausible factor is that the pKi score of ZINC01009357 of 7.86 is significantly higher than that of ZINC37864225, which is 6.57. This suggests that ZINC01009357 was a better representation of the ideal binding mode of an H1R inverse agonist, while ZINC37864225 was a poorer representation of an ideal binding mode for an H1R ligand. Further analyzing the approach used to select these two ligands, partially relying on the visual inspection of binding modes to determine an ideal representation of binding mode is a rather subjective approach, in contract to using measured binding scores which are more accurate and quantitative. It is therefore possible that inaccurate factors were taken into account during the visual inspection, or that a critical binding feature of another, and perhaps better representative ligand was overlooked.

Also, although the ZINC37864225 model has a higher mean absolute error, this does not leave it significantly less reliable. The higher mean absolute error plays into the fact that there is a large amount of flexibility in the generation of pharmacophore data. Especially our use of two separate databases and the production of separate models plays into this effect. The model also has a high correlation coefficient, which further validates the outcomes of our model. The ZINC01009357 based model has a significantly more modest mean absolute error of .189 and a high correlation coefficient of .934, also making it a valid model.

Our novel ligands ZINC37864225 and ZINC01009357 have further shown to possess relatively good affinities when compared to the pKi of other known H1R ligands. This can be well visualized in figures16A and 16B, which show these two ligands as red squares, while known ligands are expressed as blue diamonds. The fact that our novel ligands express a respectable affinity in comparison to known ligands suggests that the features we predicted as being crucial for relatively high affinity binding are likely found in reality as well. Our novel ligands represent respectable potential ligands, and would be interesting candidates for further research or development.

CONCLUSION

Based on the presented results, numerous ligand residues have been determined to represent affinity-affecting points between the ligand the binding pocket. In cluster 13 these have been determined as a high hydrophobic moiety and an aromatic residue within a binding pocket. Cluster 19 features have been identified as the presence of a polar residue near polar residues K4.99 and H7.35, two hydrophobic residues, one placed near residue W.648 and the other ahead of residues K4.99 and 7.35, and, finally, a hydrogen accepting residue near residue Y3.33. These results can be explained through the visualization of the ligands from the cluster with the probe points.

The identification of these features allowed us to compare the novel ligands produced by a docking study that produced two groups of both unrestricted and restricted ligands, which confirmed that an interaction with W6.48 is especially important for the relatively high affinity binding of a ligand within the H_1R receptor, as well as interactions with Y3.33. This was most evident by the fact that both groups commonly interacted with these two moieties, even without imposing restrictions upon the ligands. It was also observed that these interactions were most common in ligands with a high binding affinity after the initial FlexX docking and scoring had been carried out.

Aromatic interactions with F6.52 were also commonly identified in both ligand groups, and thus serve as an interesting interaction to further pursue as influential on the high affinity binding between inverse agonists and H_1R.

Furthermore, a number of novel ligands were identified that are predicted to bind with good affinity to the H_1 receptor by the FlexX docking and scoring method. These can be seen back in table 3. It would be an interesting point of further research to further develop these ligands in a laboratory setting and test the actual affinities of these ligands. Ligands ZINC37864225 and ZINC01009357 were specifically chosen as the two most promising potential H_1R ligands, with respective pK_i scores of 6.75 and 7.69. It is important to note that these pK_i scores were not experimentally validated.

Two models were created based on these two selected ligands to represent the ideal pharmacophore features for relatively high affinity H_1R binding. These models predict the pK_i of a molecule based on what we believe are crucial binding characteristics, and are shown in Appendices A1 and A2. The models have relatively high correlation coefficients, and therefore represent accurate models of our six probe points, although the model representing ZINC37864225 does have a relatively large mean absolute error, making it less reliable. These two models were used to validate their respective representative ligands as well as accurately predict the pK_i of known H_1R ligands, as can be seen in figure 15A and 15B. The high corresponding correlation coefficients further confirm the accurate predictive power of both models of a ligand's pK_i value.

Based on these results, we can conclude that both the ZINC37864225 and ZINC01009357 based models show accurate predictive power of a ligands pK_i. Overall, the ZINC01009357 based model has higher correlation scores as well as a lower mean absolute error. The high correlation coefficient (r^2) of both models further confirms that the features we initially chose to base our models on are important for determining the likely affinity of a ligand in the H_1R receptor. The novel ligands that we chose to represent ideal pharmacophore features show respectable binding affinity values in comparison to known H_1R ligands. These ligands can be considered interesting candidates as H_1R inverse agonists.

Another conclusion that has been drawn from this project is that clusters with less overall structural similarity produce less affinity predicting features. This lack of similarity is due to the reduced strictness of MACCS based clustering. The lack of produced features is an expected result, as only a small number of similar binding features are likely present in cluster with ligands that possess few similar characteristics in general. This is especially true when compared to a cluster consistent of groups that have a high structural similarity.

Furthermore, the production of good predictive models does not necessarily indicate that the features are easily identifiable or explainable. Early developed clusters, numbers 1 -10, all produced good predictive models, however, they were not chosen as the clusters where features where most easily identifiable and explainable. Clusters 13 and 19 were indeed the ones that had the most explainable features when visualized using MOE. Furthermore, poses that are ranked with highest docking scores are not necessarily the best overall pose for binding, leaving visual inspection a crucial component.

The importance of identifying features that

carry the most influence on binding affinity is crucial for our understanding of ligand-protein interactions and for the further identification of novel ligands (4). Structure based research has become a focus point for researchers in the drug discovery field, and especially through the use of QSAR, the identification of new features will allow for the production of ligands that have a desired binding affinity to produce desired responses and avoid unwanted side effects. Through methods such as those used in this project, features that are identified as crucial factors in binding affinity can be emphasized in the production of and identification of new lead compounds.

REFERENCES

1. ***Structure of the human histamine H1receptor complex with doxepin.*** Shimamura, T., et al., et al. 475, s.l. : Nature, 2011, Vol. 22, pp. 65-70.

2. Shahid, M., et al., et al. Biological and Pharmacological Aspects of Histamine Receptors and their Ligands. ***Biomedical Aspects of Histamine.*** Dordrecht : Spinger, 2011.

3. ***Structure-based drug screening for G-protein-coupled receptors***. Shoichet, B. and Kobilka, B. 5, s.l. : Trends in Pharmacological Science, 2012, Vol. 33, pp. 268–272.

4. ***The structure and function of G protein-coupled receptors.*** Rosenbaum, D. M., Rasmussen, S. G. and Kobilka, B. K. s.l. : Nature, 2009, Vol. 459, pp. 356–363.

5. ***Making virtual screening a reality.*** Koh, J. 12, s.l. : PNAS, 2003, Vol. 100, pp. 6902–6903.

6. ***Fragment-Based Drug Discovery***. Erlanson, D., McDowell, R. and O'Brien, T. 14, s.l. : Journal of Medicinal Chemistry, 2007, Vol. 47, pp. 3463-3482.

7. ***A Novel QSAR Model for evaluating and Predicting the Inhibition Avtivity of H1-Receptor Antagonist : A Series of Thienopyrimidine Derivitives***. Singh, M., Singh, S. and Chhabriab, M. 1, s.l. : Journal of Drug Discovery and Theraputics, 2012, Vol. 2, pp. 6-15.

8. ***3D-QSAR in Drug Design.*** Verma, J., Khedkar, V. and Coutinho, E. s.l. : Current Topics in Medicinal Chemistry, 2010, Vol. 10.

9. ***2D-QSAR Models: Hansch and Free Wilson Analyses.*** Kubinyi, H. s.l. : Comput. Med. Chem. Drug Discovery, 2004.

10. ***How to Recognize and Workaround Pitfalls in QSAR Studies: A Critical Review.*** Scior, T., et al., et al. s.l. : Current Medicinal Chemistry, 2009, Vol. 16.

11. ***QSAR and 3D QSAR in Drug Design. Part 1: methodology.*** Kubinyi, H. s.l. : Elsevier, 1997, Vol. 2.

12. ***In Silico Binding Characteristics Between Human Histamine H1 Receptor and Antagonists***. Want, X., et al., et al. s.l. : J Mol Model, 2010, Vol. 16.

13. ***Pharmacophore Modeling, Virtual Screening and Molecular Docking Studies for Identification of New Inverse Agonists of Human Histamine H1 Receptor.*** Thangapandian, S., et al., et al. 1, s.l. : Bull. Korean Chem Soc. , 2010, Vol. 31.

14. ***Structure-Function of the G Protein Coupled Receptor Superfamily.*** Katritch, V., Cherezov, V. and Stevens, R. s.l. : Annu. Rev. Pharmacol. Toxicology, 2013, Vol. 53, pp. 531–56.

15. ***Agonist-bound adenosine A2A receptor structures reveal common features of GPCR activation.*** Lebon, G., et al., et al. s.l. : Nature, 2011, Vol. 521.

16. ***Structure of an agonist-bound human A2A adenosine receptor.*** Xu, F., et al., et al. s.l. : Science, 2011, Vol. 332.

17. ***Molecular Determinants of Ligand Binding Modes in the Histamine H4 Receptor: Linking Ligand-Based Three-Dimensional Quantitative Structure–Activity Relationship (3D-QSAR) Models to in Silico Guided Receptor Mutagenesis Studies.*** Istyastono, E., et al., et al. s.l. : Journal of Medicinal Chemistry, 2011, Vol. 54.

18. ***Molecular determinants of ligand binding modes in the histamine H(4) receptor: linking ligand-based three-dimensional quantitative structure-activity relationship (3D-QSAR) models to in silico guided receptor mutagenesis studies***. Istyastono EP, Nijmeijer S, Lim HD, van de Stolpe, A., et al., et al. 23, s.l. : J Med Chem, 2011, Vol. 54.

19. ***The G-protein-coupled receptors in the human genome form five main families. Phylogenetic analysis, paralogon groups, and fingerprints.*** Fredriksson, R., et al., et al. s.l. : Molecular Pharmocology, 2003, Vol. 63, pp. 1256-1272.

20. ***The G-Protein-Coupled Receptors in the Human Genome Form Five Main Families. Phylogenetic Analysis, Paralogon Groups, and Fingerprints.*** Fredriksson, R., et al., et al. s.l. : Molecular Pharmocology, 2003, Vol. 53.

21. ***GPCRDB information system for G protein-coupled receptors.*** Horn, F., et al., et al. 1, s.l. : Nucl. Acids Res. , 2003, Vol. 31.

22. ***GPCRTree: online hierarchical classification of GPCR function.*** Davies, M., et al., et al. s.l. : BMC Research Notes, 2008, Vol. 1, p. 67.

23. ***Historical review: a brief history and personal retrospective of seven-transmembrane receptors.*** Lefkowitz, R.J. s.l. : Trends Pharmacol. Sci., 2004, Vol. 25, pp. 413–422.

24. ***The GRAFS classification system of G-protein coupled receptors in comparative perspective.*** Schiöth, H. and Fredriksson, R. s.l. : General and Comparative Endocrinolgy, 2006, Vol. 142.

25. ***Structure of the human histamine H1 receptor complex with doxepin.*** Shimamura, Tatsuro, et al., et al. 2011, Nature, Vol. 475, pp. 65-72.

26. ***The physiological action of beta-iminazolylethylamine.*** Dale, H. and Laidlaw, P. s.l. : Journal of Physiology, 1910, Vol. 41.

27. ***Histamine, Histamine Receptors, and their Role in Immunomodulation: An Updated systematic Review.*** Shahid, M., et al., et al. s.l. : The Open Immunology Journal, 2009, Vol. 2.

28. ***Histamine and H1-antihistamines: Celebrating a century of progress.*** Estelle, F. and Simons, R. s.l. : Journal of allergy and Clinical immunology, 2011, Vol. 128, pp. 1139-1150.

29. ***Advances in H1-Antihistamines.*** Estelle, F. and Simons, R. 21, 2004, The New England Journal of Medicine, Vol. 351, pp. 2203-2217.

30. ***Action protectrice des ethers phenolque au cours de l'intoxication histaminique.*** Bovet, D. and Staub, A. s.l. : C. R. Soc. Biol. Ses. Fil, 1937, Vol. 123.

31. ***Receptors mediating some actions of histamine.*** Schild, H. and Ash, A. s.l. : Br J Pharmacol, 1966, Vol. 27.

32. ***Milestones in the biology and pharmacology of H1R antagonists .*** Marone, G. s.l. : Allergy , 1997, Vol. 52.

33. ***Histamine, histamine receptors and antihistamines: new concepts.*** Criado, P., Criado, R. and Maruta, C. Filho, C. s.l. : The Brazilian Annals of Dermatology, 2010, Vol. 85.

34. ***Risk of first-generation H1-antihistamines: a GA position paper.*** Church, M.K. and al., et. s.l. : Allergy, 2010, Vol. 65.

35. ***Expression cloning of a cDNA encoding the bovine histamine H1 receptor.*** Yamashita, M. and al, et. s.l. : Proc. Natl. Acad. Sci. USA, 1991, Vol. 88.

36. ***H1 -Antihistamines: inverse agonism, anti-inflammatory actions and cardiac effects.*** Leurs, R., Church, M. K. and Taglialatela, M. s.l. : Clin. Exp. Allergy , 2002, Vol. 32.

37. ***Constitutive activity of the histamine H1 receptor reveals inverse agonism of histamine H1 receptor antagonists.*** Bakker, R. A., Wieland, K., Timmerman, H. & Leurs, R. s.l. : Eur. J. Pharmacol., 2000, Vol. 387.

38. ***Inverse agonism at G protein-coupled receptors: (patho)physiological relevance and implications for drug discovery.*** de Ligt, R., Kourounakis, A. and IJzerman, A. s.l. : Br J Pharmocology, 2001, Vol. 130.

39. ***A novel QSAR model for evaluating and predicting the inhibition activity of H1-receptor antagonists: a series of thienopyrimidine derivatives.*** Singh, M,, Singh, S. and Chabria, M. s.l. : Journal of Drug Development and Theraputics, 2012, Vol. 2.

40. On Two Novel Parameters for Validation of Predictive QSAR Models. Roy, P., et al., et al. s.l. : Molecules, 2009, Vol. 14.

41. ***Crystal Structure of Rhodopsin:*** A G ProteinÐCoupled Receptor. Palczewski, K. and al., et. s.l. : Science , 2000, Vol. 289.

42. ***Receptor activation: what does the rhodopsin structure tell us?*** Meng, C. and Bourne, H. s.l. : Trends in Pharmocological Sciences, 2001, Vol. 22.

43. ***Customizing G Protein-Coupled Receptor Models for Structure-Based virtual screening.*** de Graaf, C. and Rognan, D. s.l. : Current Pharmaceutical Design, 2009, Vol. 15.

44. ***Structure-based drug screening for G-protein-coupled receptors.*** Shoichet, B. and Kobilka, B. s.l. : Trends in Pharmological Sciences, 2012, Vol. 33.

45. ***Outstanding challenges in protein–ligand docking andstructure-based virtual screening.*** Waszkowycz, B., Clark, D. and Gancia, E. 2, s.l. : WIREs Computational Molecular Science, 2011, Vol. 1, pp. 229-259.

46. ***PLANTS: Application of Ant Colony Optimization to Structure-Based Drug Design.*** Korb, O., Stützle, T. and T.E., Exner. s.l. : Lecture Notes in Computer Science, 2006, Vol. 4150, pp. 247-258.

47. ***Structural Interaction Fingerprint (SIFt): A Novel Method for Analyzing Three-Dimensional Protein?Ligand Binding Interactions.*** Deng, Z., Chuaqui, C. and Singh, J. 2, s.l. : Journal of Medicinal Chemistry, 2004, Vol. 47, pp. 337–344.

48. ***GRID/CPCA: A New Computational Tool To Design Selective Ligands.*** Kastenholz, M., et al., et al. 16, s.l. : Journal of Medicinal Chemistry, 2000, Vol. 43, pp. 3033–3044.

49. ***Data mining in bioinformatics using Weka.*** Frank, E., et al., et al. 19, s.l. : Bioinformatics, 2004, Vol. 20, pp. 2479-2481.

50. ***Ultrafast de novo docking combining pharmacophores and combinatorics.*** Gastreich, M., et al., et al. s.l. : Journal of Computer-aided Molecular Design, 2006, Vol. 20.

51. ***Docking of Hydrophobic ligands with interaction-based matching algorithms.*** Rarery, M., Kramer, B. and Lengauer, T. 3, s.l. : Bioinformatics, 1999, Vol. 15.

52. Gaulton, A., et al., et al. ´ChEMBL: A Large-scale Bioactivity Database For Chemical Biology And Drug Discovery. s.l. : Nucl. Acids Res. Database Issue, 2011.

53. ChemAxon. Calculator Plug Ins 5.2.0 edn. s.l. : ChemAxon, 2009.

54. Inc., Chemical Computing Group. Molecular Operating Environment (MOE). Montreal, QC, Canada : s.n., 2011. Vol. 2010.11.

55. ***Linking agonist binding to histamine H1 receptor activation.*** Jongejan, A., et al., et al. s.l. : Nature Chemical Biology, 2005, Vol. 1, pp. 98 - 103 .

56. ***The WEKA Data Mining Software: An Update;***. Hall, M., et al., et al. 1, s.l. : SIGKDD Explorations, 2009, Vol. 11.

57. ***Mutational analysis of the histamine H1-receptor binding pocket of histaprodifens.*** Bruysters, M., et al., et al. 1-3, s.l. : European Journal of Pharmacology, 2004, Vol. 487.

58. ***Mutational analysis of the antagonist-binding site of the histamine H(1) receptor.*** Wieland, K., et al., et al. 42, s.l. : Journal of Biological Chemistry, 1999, Vol. 274.

59. ***Defining the Applicability Domain of QSAR models: An overview.*** Sahigara, F. s.l. : Molecular Descriptors, 2012.

60. ***Crystal Structure of the B2 adrenergic receptor–Gs protein complex.*** Rasmussen, S.G., et al., et al. s.l. : Nature, 2011, Vol. 549.

APPENDICES

A1: SIMILARITY SEARCH OF ZINC37864225

Ligands of ZINC37864225 Based Model			
ChEMBL ID	**SMILES**	**pK_i (HR H_1)**	**Reference**
CHEMBL1201257	N(CCCC12CCC(c3c1cccc3)c1c2cccc1)C	8.8	PMID: 19091563
CHEMBL348302	N(CCCC1c2c(Cc3c1cccc3)cccc2)C	8.5	PMID: 19700330
CHEMBL445	N(CC\C=C/1\c2c(CCc3c\1cccc3)cccc2)C	7.3	DrugMatrix
CHEMBL595158	N(CCC1c2c(Cc3c1cccc3)cccc2)C	7.3	PMID: 19700330
CHEMBL593494	N(CCC(c1ccccc1)c1ccccc1)C	7.2	PMID: 19700330
CHEMBL160893	NCCC1c2c(Cc3c1cccc3)cccc2	6.9	PMID: 19700330
CHEMBL158780	NCCCC1c2c(Cc3c1cccc3)cccc2	6.8	PMID: 19700330
CHEMBL47482	NCC1c2c(Cc3c1cccc3)cccc2	6.7	PMID: 19700330
CHEMBL73307	N(CC1c2c(Cc3c1cccc3)cccc2)C	6.7	PMID: 19700330
CHEMBL594138	N(CCCC(c1ccccc1)c1ccccc1)C	6.4	PMID: 19700330
CHEMBL1923524	n1(c2c(cccc2C)c(c1)CCN)Cc1ccccc1	6.3	PMID: 22007643
CHEMBL343324	O(CCCNC)c1c2c(ccc1)cccc2	6.1	PMID: 22007643
CHEMBL597528	N(CC1c2c(Cc3c1cccc3)cccc2)CCCCc1ccccc1	6.0	PMID: 20045641
CHEMBL593734	NCCCC(c1ccccc1)c1ccccc1	5.8	PMID: 19700330
CHEMBL609579	NCCC(c1ccccc1)c1ccccc1	5.6	PMID: 19700330
CHEMBL1923535	O(c1ccccc1CCN)c1ccccc1	5.0	PMID: 22007643

A2: SIMILARITY SEARCH OF ZINC01009357

Ligands of ZINC01009357 Based Model			
Mol	**SMILES**	**pK_i/pIC50 (HR H_1)**	**Reference**
CHEMBL1628227	O1Cc2c(cccc2)C(c2c1cccc2)=CCCN(C)C	9.8	PMID: 22007643
CHEMBL294777	O1Cc2c(cccc2)/C(/c2cc(ccc12)CCO)=C/CCN(C)C	9.2	PMID: 1350797
CHEMBL1092598	s1ccnc1[C@H](C)C=1c2c(CC=1CCN(C)C)cccc2	9.1	PMID: 20227880
CHEMBL629	N(CC\C=C/1\c2c(CCc3c\1cccc3)cccc2)(C)C	9.0	PMID: 19091563
CHEMBL534	s1c2c(cc1)\C(\c1c(CC2=O)cccc1)=C\1/CCN(CC/1)C	9.0	PMID: 21470866
CHEMBL1633	s1c2c(cc1)\C(\c1c(CC2=O)cccc1)=C\1/CCN(CC/1)C	9.0	PMID: 19362477
CHEMBL1090528	s1ccnc1[C@H](C)C=1c2c(CC=1CCN(C)C)cc(cc2)C	8.7	PMID: 20227880
CHEMBL564	S1c2c(N(c3c1cccc3)CCCN(C)C)cccc2	8.5	DrugMatrix
CHEMBL285802	Clc1cc2c(Sc3c(C=C2OCCN(C)C)cccc3)cc1	8.5	PMID: 14998318
CHEMBL1092599	s1cc(nc1[C@H](C)C=1c2c(CC=1CCN(C)C)cccc2)C	8.5	PMID: 20227880
CHEMBL908	Clc1cc\2c(Sc3c(cccc3)/C/2=C/CCN(C)C)cc1	8.4	PMID: 19091563
CHEMBL1259173	S1c2c(cc(cc2)CNC(=O)C)[C@H](N2CCN(CC2)C)Cc2c1cccc2	8.4	PMID: 20857909
CHEMBL1669425	n1ccncc1[C@H](C)C=1c2c(CC=1CCN-(Cc1ccncc1)C)cccc2	8.3	PMID: 21232954
CHEMBL1669419	s1cccc1CN(CCC=1Cc2c(cccc2)C=1[C@@H](C)c1nccnc1)C	8.2	PMID: 21232954
CHEMBL1669422	[nH]1ccnc1CN(CCC=1Cc2c(cccc2)C=1[C@@H](C)c1nccnc1)C	8.1	PMID: 21232954
CHEMBL540982	s1c2c(cccc2)c(Cc2ccc(F)cc2)c1CCN(C)C	8.0	PMID: 19663387
CHEMBL1669424	n1ccccc1CN(CCC=1Cc2c(cccc2)C=1[C@@H](C)c1nccnc1)C	7.9	PMID: 21232954
CHEMBL395110	S1c2c(N(c3c1cccc3)CC1CCCN(C1)C)cccc2	7.6	DrugMatrix
CHEMBL1669426	n1ccncc1CN(CCC=1Cc2c(cccc2)C=1[C@@H](C)c1nccnc1)C	7.6	PMID: 21232954
CHEMBL445	N(CC\C=C/1\c2c(CCc3c\1cccc3)cccc2)C	7.3	DrugMatrix
CHEMBL595158	N(CCC1c2c(Cc3c1cccc3)cccc2)C	7.3	PMID: 19700330
CHEMBL1669420	s1ccnc1CN(CCC=1Cc2c(cccc2)C=1[C@@H](C)c1nccnc1)C	7.3	PMID: 21232954

Visual Recognition in Museum Guide Apps: Do Visitors Want It?

Leonard Wein

ABSTRACT

Museums are exploring the potential of mobile applications (apps) to improve visitors' museum experiences. In this context, visual recognition has been proposed as a novel, more natural and unobtrusive method to access background information in museum guides. While technical aspects have been explored, it has yet to be determined whether visitors actually want to use visual recognition. This research empirically evaluates visitors' perceptions of visual recognition compared to QR and number codes. The three methods are implemented in a Museum Guide prototype and tested in two museums with regular visitors (N = 89) via a field experiment. The goal of this research is to inform future developments by assessing which method visitors prefer and to identify the reasons that the preferences are based on. The results of the experiment show a clear preference for visual recognition across museum types and demographic groups regardless of prior experience. Distance, enjoyment and ease of use are identified as the main factors determining the preference for VR. Based on the results, the recommendation is to focus development efforts on visual recognition.

1. INTRODUCTION

Emerging mobile technologies have opened new possibilities for museums to engage their visitors. The question of how to utilize these possibilities is gaining importance. Smartphone ownership in the UK and the US has reached 50% in 2012 (IDC & Facebook, 2013, p. 3; V&A, 2013, p. 27) and more importantly, its use is becoming increasingly ubiquitous: 79% of respondents stated that they carry their smartphone during all but two hours of the day (IDC & Facebook, 2013, p. 14) and Google found that 89% use their smartphone throughout the day (Google & Ipsos OTX, 2011, p. 6). In addition, smartphone developments in museums have also been driven by the expectation to provide improved education, customization and emotional experiences, which are considered primary objectives of museums (Monod & Klein, 2005, p. 2870; Poria, Biran, & Reichel, 2009). Therefore, the number and diversity of technologies used in mobile museum applications (apps) have increased significantly during the past four years: 49% of surveyed museums in the US and 37% in the UK have started offering mobile-based experiences since 2009 with a growth rate of 36% between 2011 and 2012 (American Alliance of Museums, 2012, p. 28; Museums Association, 2012, p. 6).

However, while researchers and museums have "focused on technical issues and challenges" (Economou & Meintani, 2011, p. 3; See also Emmanouilidis, Koutsiamanis, & Tasidou, 2013; Kenteris, Gavalas, & Economou, 2010), little effort has been made to assess, whether the proposed mean is the "best way to meet the actual objectives" (Damala, 2006, p. 7) and to "examine their effect on the museum visit" (Economou & Meintani, 2011, p. 3). Pallud and Monod (2010, p. 562) confirm that the evaluation of mobile systems in museums in general has received "little attention." Hence, it is not surprising that museums report "encouraging visitors to use the mobile experience" to be a key challenge (Tallon, 2013). The situation bears the risk of a mismatch between what the museum expects and the actual user perceptions of the mobile apps. Therefore, the American Association of Museums concludes that

"museums are keenly interested in [...] research on mobile users (visitors) [...] to fill the knowledge gap about mobile technology" (2011, p. 5).

One technology in which this disparity between popularity and lack of corresponding knowledge about visitor preferences applies is visual recognition (VR). VR has received particular attention from the research community for its expected potential in improving the user experience. Using VR, visitors can access background information about an artwork from a distance without shifting attention from the artwork by pointing the smartphone camera at it. This movement corresponds to the familiar picture-taking motion, which has been found to be the most common activity of smartphone users (American Alliance of Museums, 2012, p. 17) and if allowed, can frequently be observed in museums (Figure 1, Leighton, 2007).

Figure 1: *Visitors taking photos with the smartphone in the Van Gogh Museum. The museum allows taking pictures since its reopening in May 2013. (Source: Laan, 2013)*

The underlying hypothesis seems to be that VR in museum guide apps facilitates access to background information in a more natural and unobtrusive way than alternative methods (such as lists, number codes or more recently QR codes). This is likely to be because it does not require users to actively go out of their way, distracting them from the natural interaction with the artworks. While the technical feasibility has been tested, virtually no noteworthy user testing has been conducted to confirm the underlying hypothesis.

This research thus aims to test this hypothesis through the following two research questions:

RQ 1: Do museum visitors want visual recognition?
RQ 2: What are the reasons for visitor preferences?

In summary, the three main contributions of this research are to provide reliable, empirical evidence for visitor perceptions of visual recognition to inform further mobile developments in museums; to demonstrate the efficacy of the ORB visual recognition algorithm in phone-based museum guides; and to showcase the importance of systematic, experimental user evaluation to facilitate informed decisions regarding technologies in museums. The research questions are substantiated through a literature review in the next section (section 2). Consequently, to answer the research questions, a Museum Guide app was developed that features visual recognition as well as QR codes and number codes for comparison to access background information of artworks (section 3). Based on a comprehensive literature review, a field experiment was designed and thereafter conducted with regular museum visitors in two museums in the Netherlands (section 4). The results are presented (section 5); discussed (section 6) and conclusions are drawn (section 7).

2. BACKGROUND AND RELATED WORK

2.1. MUSEUM GUIDES AND ACCESS METHODS

Museum guides are a means for museums to provide information and interpretation of artworks to visitors in order to improve their museum experience ("improving the interpretive mission," Monod & Klein, 2005, p. 2870). Museum guides can have various formats (e.g. professional tour guide, printed leaflets, audio guides, mobile apps) and can include additional contextual information (visitor information, exhibition context, floor plan, etc.). This research focuses on smartphone-based museum guide applications ('museum guide apps') that provide background information on artworks, and in particular on how this information is made accessible to users. For this purpose, access methods are defined as the physical interaction that allows a user to obtain background information about a specific artwork using a museum guide app (Table 1 presents common access methods). Access methods are important because they significantly influence the visitor's ability to "focus on the artworks, not on the technology" – a critical success factor for museum guides (Kuflik et al., 2011, p. 11:1).

Method	Description
List Search	Common method in current museum apps. Requires users to select the desired artwork from a list, similar to browsing a leaflet or catalogue. Tedious for larger exhibitions.
Number Codes	Standard in conventional audio guides. Users input a number (two to five digits, normally three) found next to artworks. Simple, but requires multiple user inputs.
QR Codes	Requires users to scan a two-dimensional, machine-readable code with the smartphone camera (20-80 cm distance) applied next to the artwork. Technically suitable and trending in museums, but requires QR reader app and reportedly not visually appealing (e.g. American Alliance of Museums, 2012; Cairns, 2012). Requires short distance for scanning.
Visual Recognition	Requires users to point smartphone camera at artwork. Directly recognizes artworks based on visual features. Works from a distance and no physical modification required. Contains risk of recognition errors (Möller, Diewald, Roalter, & Kranz, 2012).
RFID/NFC tags	Users touch a radio frequency tag with their smartphone or reading device (Groninger Museum, 2010; Möller et al., 2012). Requires direct contact.
Location tracking	Determining users location using WIFI/GPS-based tracking and displaying nearby artworks for selection (e.g. Alfandari, 2013; Möller et al., 2012). Requires multiple WIFI network points; risk of errors.

Table 1: *Overview of access methods for museum guides*

2.2. VISUAL RECOGNITION IN MUSEUM GUIDES

Noting its potential for more natural, unobtrusive interaction with artworks, visual recognition (VR) was proposed as an access method long before the emergence of smartphones in early conceptual papers on the potential of mobile museum guides (Abowd & Mynatt, 2000; Long, Kooper, Abowd, & Atkeson, 1996; Rekimoto & Nagao, 1995). Figure 2 shows Rekimoto and Nagao's (1995) concept to embed visual recognition in the natural interaction with artworks.

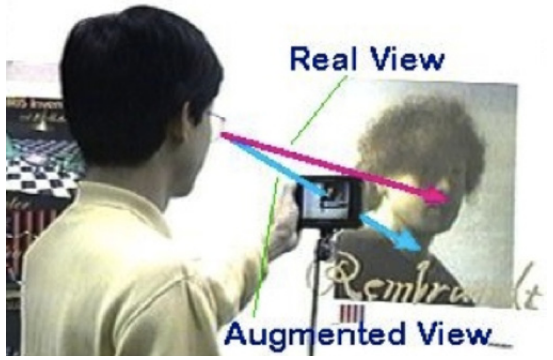


Figure 2: *"Magnifying glass metaphor" for natural interaction with artwork using VR (Source: Rekimoto & Nagao, 1995, p. 3)*

Since these early works, visual recognition in the museum space has been investigated in numerous research projects. However, research before the introduction of smartphones (2007/2008) faced significant interaction and processing restrictions and should therefore be considered experimental proofs of concept (e.g. Albertini, Brunelli, Stock, & Zancanaro, 2005; Andreatta & Leonardi, 2006; Bay, Fasel, & Gool, 2006; Föckler, Zeidler, & Brombach, 2005; Germann, 2006).

More recently, Ruf and Detyniecki (2009) and Ruf, Kokiopoulou and Detyniecki (2010) tested visual recognition algorithms and matching approaches with respect to recognition performance and processing time using a client-server architecture. Their research showed the technical suitability of using mobile phones for the visual recognition of artworks. Jang and Woo (2011) proposed a semi-automatic recognition process requiring the user to indicate the relative area of the artwork in the picture for improved recognition. Further relevant research has been conducted for augmented reality (AR) and indoor location tracking applications (e.g. Kawaji & Hatada, 2010; Möller et al., 2012) that employ visual recognition techniques (often combined with WIFI/GPS data) for use in museums.

In practice, many museums have experimented with VR-based applications. Most importantly, the

Metropolitan Museum (MET) in New York partnered with Google in 2011 to index their entire collection for recognition with Google Goggles, Google's universal visual recognition app (Campbell, 2011). Using Google Goggles, visitors can take a picture of a painting at the MET, Google analyses it on its servers and returns a link to background information on the MET's mobile website. VR has also been used in more creative applications, for example allowing the user to manipulate 3D models of actual objects exhibited in front of them[1], and showing videos on top of paintings to make their stories come to life[2]. Some museums have also developed VR-based apps for cultural outdoor tours (often using commercial AR providers like Layar[3].

2.3. DO VISITORS ACTUALLY WANT VISUAL RECOGNITION?

The previous review of the field has shown that there is significant interest from museums and the research community in visual recognition, but do visitors actually want to use it? Surprisingly, the question whether museum visitors actually perceive the proposed benefits of the technology and want to use it over less sophisticated methods has not yet been addressed.

Based on Damala's (2006, p. 4) survey of existing evaluation practices for mobile Museum Guides (conventional audio guides and purpose-built systems), usability was chosen as a proxy to assess user experience and satisfaction in this research (also in Othman, Petrie, & Power, 2011; Pazmino & Lyons, 2011). Usability is defined in ISO 9241-11 (1998) as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." The reviewed literature, however, only evaluates VR's effectiveness (recognition performance) and efficiency (processing time) for museum guides through lab tests (with photos taken previously in the museum). It misses the "specified user," their "satisfaction" as well as the "specified context of use." This research will also inspect the importance of these attributes in capturing usability.

In fact, in the only comparative usability assessment of VR that was found provides evidence against the usability of VR. Möller et al. (2012) tested VR, text-based access, NFC tags and barcodes in a medication package identifier. VR scored only third, which was explained by its longer processing time. Due to the questionable sample (16 participants recruited among acquaintances) and the "rich and dynamic [situated] use contexts [that] have to be accounted for in mobile evaluation methods" (Nielsen, Overgaard, Pedersen, Stage, & Stenild, 2006; Pedell, Graham, Kjeldskov, & Davies, 2003, p. 9), the generalizability to the museum setting might be significantly limited. Nevertheless, the findings highlight the significance of assessing hypotheses about user preferences through field tests in realistic environments and with representative users (i.e. regular museum visitors interested in background information) motivating the conceptualization of this research.

In order to actually evaluate user preferences in the field, the evaluation literature was consulted to elicit relevant usability metrics. Drawing on Brooke's System Usability Scale (1996), Finstad's Usability Metric for User Experience scale (2010) and Othman et al.'s Multimedia Guide Scale (2011), as well as Damala (2006), the following factors were identified that will guide this research:

- Effectiveness (recognition performance/ Accuracy)
- Efficiency (processing time/speed)
- Enjoyability
- Ease of use
- Content of the app
- Aesthetics
- Facilitator for situated experience with artworks (natural, unobtrusive)

[1] http://www.museumsandtheweb.com/mw2012/papers/augmented_reality_what_reality_can _we_ learn_fr

[2] http://mobilemuseum.org.uk/2011/11/sukiennice-a-new-dimension/

[3] http://www.layar.com

3.IMPLEMENTING THE MUSEUM GUIDE APP

3.1. PURPOSE AND REQUIREMENTS

The purpose of the Museum Guide app was to enable the assessment of user perceptions of visual recognition. QR codes and Number codes were chosen as alternative access methods to allow a comparative assessment (dependent variable). Number codes were chosen because they are the conventional, low-tech, standard method used in audio guides around the world, and hence the most familiar method to visitors. QR codes were chosen for their supposed speed/ efficiency, their more recent use in several museum projects (e.g. Cairns, 2012; Groninger Museum, 2010), and because they were preferred over VR in Möller et al. (2012). In fact, the Museums Associations industry survey (2012, pp. 13, 28) finds QR codes to be the most widely used 'new' mobile feature in the UK and the US and at the top of expansion plans in 2012. An additional benefit was that they could both be easily implemented on smartphones with minimal requirements regarding the museum space (only application of removable paper stickers).

The Museum Guide prototype was conceived with its use for the field experiment in mind. Creating a satisfying and meaningful user experience was necessary for the reliable assessment of access methods, because "users tend to be unable to distinguish between overall system performance and specific characteristics" (Kuflik et al., 2011, p. 11:15) and because asking visitors to evaluate access methods in isolation would not have evoked an interest to participate. Therefore, the Museum Guide app was conceived to be actually useful for museum visitors; to make them want to use it. Although the research objective was to assess access methods, the design of the Museum Guide was aligned with the users' objective to obtain meaningful high quality background information on the selected artworks regardless of the access method (independent variable).

3.2 DEVELOPMENT PROCESS AND ATTRIBUTION

The development of the Museum Guide app prototype was made possible through the generous support of the Beta Beurs undergraduate research grant. After developing the concept and design of the app, a bidding for developers was conducted on two major freelancing portals[4] At the end of the bidding process, Andreas Osowski, an Android developer with experience in computer vision was chosen. He completed the technical implementation of the Museum Guide app and is the author of the source code. Exclusive usage has been agreed upon. The development process was organized in several sprints marked by close collaboration on functionality and design. Extensive feedback rounds were conducted with functional and usability testing at each stage of the process and specifications were adapted as the project evolved.

3.3 PLATFORM AND ARCHITECTURE

The Museum Guide was developed for the Android platform (Android 4.1.2 'Jelly Bean'). Although most museums first develop iPhone apps (despite the overall market leadership of Android), the decision for Android was motivated mostly by practical reasons: Android apps are written in Java[5] (a widely available programming language); the openness of the platform makes development and testing easy (e.g. install the prototype app easily on several devices for the experiment); and lastly, we had access to four modern Android smartphones (Samsung I9300 Galaxy S3[6]) that made simultaneous experiments possible. The large screen and powerful processors of the Galaxy S3 (4.8 inches, 1GB Ram, 1,4GHz Quad-core) also promised an optimal performance and interaction experience.

We designed the app to be self-contained with all processing being done locally on the phone. Processing of images for visual recognition and QR codes can either be done on a remote server (client-server architecture) via a data connection, or on the phone itself (Föckler et al., 2005; Germann, 2006; Ruf et al., 2010). While most prior research uses a client-

[4] http://www.freelancer.com/ and https://www.elance.com/; the developer was recruited via freelancer.com

[5] http://www.java.com/en/

[6] http://www.samsung.com/uk/consumer/mobile-devices/smartphones/android/GT-I9300MBDBTU

server architecture due to limited mobile processing capacities, modern smartphones enable phone-based implementations with comparably fast performance (at least for smaller databases). The Museum Guide was developed with a contained, phone-based approach to gain independence from Internet availability and thus greater flexibility regarding the experiment space. Given the small database and the fast processor of the Galaxy S3, processing would most likely not have been quicker using a client-server architecture.

3.4. IMPLEMENTATION OF VISUAL RECOGNITION

The visual recognition method has been implemented using an implementation of ORB (oriented BRIEF, proposed by Rublee, Rabaud, Konolige, & Bradski, 2011) from the openCV computer vision library for Android.

The two key requirements for visual recognition algorithms are accuracy and speed. Contributing to accuracy are rotation, scale and distortion invariance (for difficult lighting and recognition from varying distances and angles), as well as local recognition. Local recognition enables matching of input that contains other elements than the artwork (e.g. a frame and wall segments) or only parts of the artwork, e.g. because another visitor is obstructing the view or because the user is very close to the artwork. Table 2 presents currently available algorithms satisfying these criteria and their sources.

Algorithm	Source
Scale-Invariant Feature Transform (SIFT)	Lowe, 1999
Speeded Up Robust Features (SURF)	Bay et al., 2006
BRISK	LEUTENEGGER, CHLI, & SIEGWART, 2011
Oriented BRIEF (ORB)	RUBLEE ET AL., 2011
FREAK	ALAHI, ORTIZ, & VANDERGHEYNST, 2012

Table 2: *Currently available algorithms for visual recognition*

Based on the good reviews in Heinly et al. (2012), Miksik and Mikolajczyk (2012) and Khvedchenia (2012) and because of its integration in openCV (an open-source computer vision library), we decided to use the ORB algorithm (Rublee et al., 2011) instead of SIFT or SURF. SIFT and SURF are standard recognition algorithms used frequently in related works (see Ruf et al., 2010 for accessible explanation; also in Miksik & Mikolajczyk, 2012; Rublee et al., 2011), but they are proprietary and use much more memory and processing power. The reviews above confirmed that ORB is equally reliable, but much faster than SIFT/SURF, because it uses binary descriptors instead of gradient distributions and locality sensitive hashing (LSH, a fast nearest neighbor search) for efficient matching. ORB also provides local feature recognition and is rotation, distortion, and scale[7] invariant.

ORB uses the FAST algorithm (Rosten & Drummond, 2006) to detect keypoints from (grayscale) input images, filters the key features using Harris score (Harris & Stephens, 1988) and computes binary descriptors using oriented BRIEF (Rublee et al., 2011). We were able to reduce and basically eliminate rejection/non-recognition and false positives by modifying parameters in the openCV implementation of ORB. The best results were obtained for a (arbitrary) distance value of 35. ORB was initialized with the following parameters: ORB::ORB([500, 1.2f, 12, 31, 0, 2, ORB::HARRIS_SCORE, 31).[8] Matching was done via brute force nearest neighbor search. The image with the highest number of matching keypoints is returned if there are at least 5 matching keypoints. In order to increase robustness of the recognition, the same artwork has to be matched twice consecutively. In contrast to most approaches in the reviewed literature, only one reference image of the artwork is required in the database for matching, keeping the database small and efficient. Descriptors for the reference images in the database are constructed every time the app is launched and saved to temporary memory for matching. VR requires installation of the OpenCV Manager app on the smartphone.

We decided to implement visual recognition with minimal input requirements following the example of Layar's augmented reality browser[9]. The app analyses the visual input from the camera at 6 frames per second, while the user sees a smooth, continuous camera view. When pointing the camera at an artwork, the app recognizes it within a few seconds and returns corresponding information. Our implementation directly returns the correct information and does not require the user to browse a list of potential matches (as in Möller et al., 2012, or Google Goggles[10]). We also tested an implementation that requires taping a button to initiate recognition similar to Google Goggles. However, an additional user input felt unnecessarily distracting (especially, because the Samsung Galaxy S3 does not have a physical photo capture button) and error messages, if no image was matched, were irritating. The functioning of VR is illustrated in Figure 3.

3.5. IMPLEMENTATION OF QR AND NUMBER CODES

The QR code method was implemented using the open source ZXing ('ZebraCrossing') QR reader library. Both QR codes and number codes are available on stickers (3.5 x 3.5 cm). The functioning of all methods is illustrated in Figure 3 and more close-up screenshots for each method are provided in Appendix D.

ZXing is popular, widely used, well-documented, easy to implement, and comes with a default UI. ZXing was embedded in the app – no separate QR reader app needed to be installed. It also guides the user by showing yellow dots when a QR code is being recognized. QR codes are scanned immediately when focusing the camera at the code from 20 to 100 cm distance and with an approximately right angle. No further input is required.

The Keypad method calls items from the database by manually inputting their ID number (a three-digit code) on the keypad and pressing 'Lookup'. The design follows the native SIM-unlock screen and familiar patterns of common museum audio guides. The inputted numbers appear on the top of the screen; the 'Erase'-button and incorrect inputs reset the display field.

3.6. USER INTERFACE AND NAVIGATION

The user interface (UI) and navigation design of the Museum Guide app follows Android's Design Principles and UI guidelines.[11] It was designed with the objectives to enable users to obtain useful information with minimal effort, and to embed the three methods in a way that allows comparison. Similar to Kuflik et al. (2011; overall system usability influences perception of individual elements), research has found that design aesthetics significantly influence usability tests (Lee & Koubek, 2010; Sonderegger & Sauer, 2010; Tractinsky, Katz, & Ikar, 2000; Tuch, Roth, Hornbæk, Opwis, & Bargas-Avila, 2012). Hence, attention was paid not only to streamline usability, but also to create pleasing aesthetics.

[7] FAST is not scale invariant, but ORB uses a scale-pyramid of the image to mediate this and create quasi-scale invariance - we found this to work well.

[8] http://docs.opencv.org/modules/features2d/doc/feature_detection_and_description.html?highlight=orb#orb-orb

[9] http://www.layar.com

[10] http://www.google.com/mobile/goggles/

[11] http://developer.android.com/design/index.html

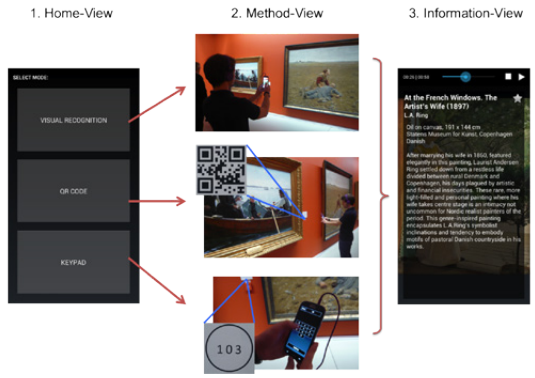


Figure 3: *Design of Home- and Information-View as well as illustration of access methods (visual recognition, QR codes and number codes). Visual recognition is the only method that does not require physical markers.*

The Museum Guide app contains three views (home-view, method-view, information-view). Design and user flow of the views are shown in Figure 3. Home- and information-view are independent of the method. The home-view provides users with the choice of method. The method-view depends on the choice of access method (VR, QR codes or Number codes) as seen in Figure 3. The information-view was inspired by the Baltimore Museum of Art web-app,[12] providing prominent meta-information, an interpretive text, the navigation of the audio player and the selected image in the background for quick visual feedback confirming the correct choice. The app runs in full screen and we use the built-in back-button according to Android design principles. The back button was disabled in the home-view to prevent users from unintentionally leaving the app.

3.7. DATABASE

The app features a lightweight, single-table SQLite database to store the artwork data. The database is created during compilation of the app from a SQL text file that can be easily accessed to add and modify content. Each artwork is an entry into the database consisting of a numeric ID (primary key), title, painter, description and time fields (text) for background information, a reference to an audio file and a reference to the sample image (both varchar). A sample database SQL file can be found in Appendix C.

3.8. LAB TESTS

3.8.1. PROCESSING TIME AND ACCURACY METHODS

This research is primarily interested in assessing visitors' perceptions of Visual Recognition (VR). However, since processing time and accuracy have been the focus so far in assessing VR and since they have been considered important contributors to user experience (Möller et al., 2012), we also assessed both metrics via a lab test. We measured processing time through a timer function as the time between initiating an access method and obtaining information. Accuracy was assessed as the fraction of correctly provided information by observing rejections and misidentifications of artworks.

First, we were interested by how much the processing time of VR increases with the number of reference images in the database (the input has to be compared to more reference images). We tested for databases containing only the input image, 32 reference images (the database used for the experiment at the Groninger Museum) and 62 reference images (the combined databases from the Groninger Museum and the Huis Marseille). Measurements were taken from 2.5 meters distance in a steady, seated position. The test image was a 1.5x2 meter wall painting at the Amsterdam University College.

Consequently, we compared processing times for VR, QR Codes and Number Codes using the database with 32 reference images (from the Groninger Museum) using the same test image as above and simulating different angles, distances and movement. Four university students were recruited for testing.

3.8.2. LAB TEST RESULTS

The complete processing time results are presented in Figure 4. The processing time increased by about 0.5 seconds between the databases (1, 32 and 62 reference images). QR Codes were the fastest (2.79 seconds, 1.57 SD), followed by Number Codes (3.20 seconds, 1.34 SD). Visual Recognition was the slowest with 4.17 seconds (.87 SD). VR simulating real usage was on average almost one second slower than in the lab test (4.17 versus 3.24 seconds).

[12] http://gomobileartbma.org/

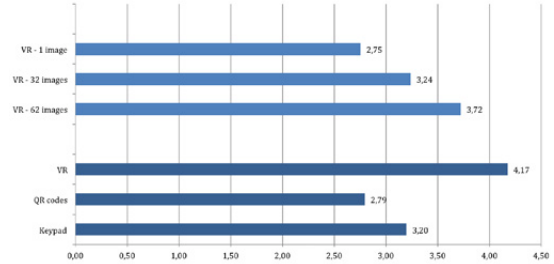


Figure 4: *Processing times in seconds. Three top rows show the measurements for VR with different database sizes (1, 32, 62). The three bottom rows show the processing times for the three methods simulating a realistic variation of movements (32 images).*

The accuracy of VR in frontal view was 100% both for the test image used for time measurements and for all images of artworks used in the experiments tested by recognition from a computer screen. The recognition was robust up to an angle of 45 degrees and images were recognized in close-up view (ca. 30 cm) as well as from a distance (ca. 5-6 m for the wall painting and 1 m for tests on an 11 inch laptop screen). Performance declined for angles smaller than 45 degrees and very long distances (when the image made up less than approximately 30 percent of the input image. Recognition was also robust when reflections and very low or strong lighting were introduced. Performance deteriorated when feature-rich surroundings were included in the input image. However, when two images were included in the input, usually the image with the larger area included in the input was recognized, unless one image had much stronger visual features.

3.8.3. LAB TEST DISCUSSION

The phone-based implementation of ORB for visual recognition (VR) of artworks featuring continuous image matching is a novelty and represents an improvement on current know-how.

Accuracy and processing time in our mobile implementation seem sufficiently good for use in an actual field experiment. Results cannot be directly compared to most technical testing mentioned above, due to significantly different measurement setups (e.g. database sizes, recognition of prepared sample photos versus photos taken during testing). Our implementation of VR (during lab tests) was significantly quicker (4.2 seconds versus 16.4 seconds) than the one by Möller et al. (2012, p. 8).

4. EXPERIMENT DESIGN

The lab tests confirming the technical efficacy of the system provide the basis for an experimental field evaluation in order to answer the initial research questions:

RQ 1: Do museum visitors want visual recognition?
RQ 2: What are the reasons for visitor preferences?

As was established earlier, the user perception of the access method of a Museum Guide app is strongly influenced by the situated nature of its use in the museum environment (Nielsen et al., 2006; Pedell et al., 2003; Xu, Spasojevic, Gao, & Jacob, 2008). Therefore, our goal was to create an experimental setup that closely simulated a regular museum visit imposing a minimum of experimental restrictions.

4.1. SETTING

The experiment was conducted during three full-day sessions in two museums in the Netherlands: the Groninger Museum in Groningen and the Museum Huis Marseille in Amsterdam. The galleries selected for the experiment were connected, spacious and well lit. For consistency, all artworks in the selected galleries were included in the experiment (to avoid confusion, since VR does not require visual markers to indicate availability of information).

The first session was conducted on April 29th, 2013 between 10.00 and 17.00 in the Museum Huis Marseille, a photography museum in the center of Amsterdam. The space hosted the exhibition POWER, showing winners of the sustainable photography price Prix Pictet.[13] The experiment space comprised the entire exhibition of 30 photographs. The photographs were distributed across three larger rooms and a narrow corridor and had dimensions of approximately 100x100 to 200x200 cm on white background, without frames, but with protective glass. A separate room was made available to instruct participants and for completing the survey.

[13] http://www.huismarseille.nl/en/exhibition/power-prix-pictet-2012

Figure 5: *Sample Artworks from Huis Marseille (above) and Groninger Museum (below)*

The second and third sessions were conducted on May 2nd and 3rd between 10.00 and 17.00 in the Groninger Museum, a museum for modern art in Groningen. Groningen is a city in the North of the Netherlands. The experiment was conducted in three connected rooms of the exhibition Nordic Art (1880 – 1920)[14] that contained 32 paintings. The paintings had golden frames with varying ornamentation and the surrounding walls were painted orange, bronze and green. The paintings had dimensions varying from 30x40 to 207x270 cm. Some paintings were horizontally stretched (landscapes), while others were vertically stretched (portraits). A small, empty room adjacent to the three selected galleries was used for instruction and completing the surveys.

4.2. SETUP

For all artworks in both museums the content for the Museum Guide was researched and produced from various sources (museum catalogue, museum website, leaflets, wall texts and independent web research on Wikipedia and art blogs). The background information contained the meta-information of the artwork (title, author, year, dimensions, material and owner where applicable) as well as an interpretive text, which was also recorded as an audio commentary. The texts for the Huis Marseille had on average about 350 words and the audio commentaries were between one to two minutes long. Content for the Groninger Museum was shorter based on feedback during the first session. The texts had between 100 to 150 words and the audio commentaries were between 30 to 60 seconds long.

Before the experiment, removable stickers with the QR and Number Codes were applied next to the artworks (3.5 x 3.5 cm). Figure 6 shows the experimental setup with the artwork and the QR and Number code stickers applied below the wall text.

Figure 6: *Experiment Setup with QR and number codes applied below the wall text.*

4.3. SAMPLING

In total, 89 participants (26 in Huis Marseille, 63 in Groninger Museum) took part in the experiment, 48 were females, and 39 were males. 44 were under thirty, 19 were between thirty and fifty and 24 were above fifty. Visitors that were photographed signed a consent form. No additional requirements applied.

For the session at the Huis Marseille, participants were recruited from outside the museum (from the street as well as through social media), due to concerns of the museum management. Free entry to the exhibition was given as an incentive. Pedestrians passing by the museum were asked whether they would be interested to visit the museum and participate in an experiment. An adapted info text was published in various student groups on Facebook[15]. The experiment was conducted during the rest day of the museum and hence, the participants had the galleries for themselves during the experiment.

At the Groninger Museum, we were able to recruit actual museum visitors that were already within the exhibition. Since the experiment took place during the last days of the Nordic Art exhibition, which attracted around 1,200 visitors per day, the galleries were well-filled providing an even more realistic field setting. The large number of visitors made it easy to quickly recruit interested participants. Visitors were approached in the galleries when they were not looking at an artwork and asked whether they would be interested to participate in an experiment. The experiment would involve using a mobile Museum Guide app to obtain background information on artworks in the galleries and to provide feedback on the experience with the app.

4.4. PROCEDURE AND DATA COLLECTION

Participants were required to try each method once in the beginning and thereafter to use the app at least three more times with any of the three methods. Hence, participants had to use the app at least six times in total (also checked via log file). Offering more than six artworks allowed participants to choose artworks they were actually interested in. Participants were free to use app for more artworks. Data was collected by means of a paper-based survey and through logging participants' interactions with the Museum Guide. The experiment was designed and conducted in English (both content and survey; translations were not possible due to time constraints). The test phones were locked[16] and tracked.[17]

Visitors that agreed to participate were given a paper-based survey and asked to read the instructions as well as to fill out the first part of the questionnaire. After completing part one, the three methods were shown on a demonstration artwork and any remaining questions were answered. The session ID was noted on the survey and recorded in the museum guide to associate survey answers and logged data. Thereafter, the participants started their visit of the designated galleries. After completing the visit, participants were asked to fill out the second part of the survey that contained specific questions about the experience with each method, the overall experience with the guide as well as three demographic questions (four pages). Since the survey was the primary source of data, the survey design is justified and substantiated in detail in section 4.5 below.

The users' interactions with the Museum Guide app were logged to a text-file on the device including timestamp and session ID. It was recorded which artworks the participant accessed and which method was used. For each logged session we aggregated the overall duration of the session, the number of artworks accessed as well as how often each of the methods was used.

4.5. SURVEY DESIGN

The questionnaire given to participants included two parts with a total of six pages that were printed double-sided (including instructions page in the beginning). Splitting the survey was meant to increase survey completion by reducing the perceived length. The complete survey is presented in Appendix A. The principles guiding the survey design were to be brief, objective, simple and specific (SurveyMonkey, 2011, p. 6). In addition, attention was paid to avoid common pitfalls (leading/loaded questions, assumptions/ jargon, asking two questions at once, leaving out or including too many choices, etc.) through several review rounds.

The instructions page contained the background of the study, disclaimers and a comprehensive stepwise guide through the experiment. The first part contained questions about prior experiences and attitudes regarding museums and mobile technology to build a participant profile. There were five multiple-choice (MC) questions on a three-point frequency scale (Never – Occasionally – Often), two binary questions (Yes – No) and one open-ended answer question conditional to the previous binary question (Q 1 – 7).

[14] http://www.groningermuseum.nl/en/exhibition/nordic-art-1880-1920

[15] http://www.facebook.com

[16] https://play.google.com/store/apps/details?id=com.domobile.applock&hl=en

[17] http://preyproject.com/

The second part started with the assessment of the usability of the three methods (Q 8 – 22). Based on Finstad's Usability Metric for User Experience (2010) to assess overall system usability and Othman, Petrie and Power's Multimedia Guide Scale (2011) to assess the overall museum guide experience, we developed the Access Method Usability Scale (AMUS) for our specific context. The AMUS contains five questions relating to five usability constructs to be evaluated on a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) as shown in Table 3.

No.	Construct	QUESTION PHRASING
Q 1	Suitability	[Method] is suitable to access information in museums.
Q 2	Enjoyability	I enjoyed using the [method].
Q 3	Speed (negative)	[Method] was too slow.
Q 4	Accuracy	[Method] was accurate.
Q 5	Ease of use (negative)	[Method] was difficult to use.

Table 3: *The five questions of the AMUS. [Method] was substituted with Visual Recognition, QR Codes and Number codes (and conjugation modified where applicable).*

Following the System Usability Scale (Brooke, 1996), two questions were coded negatively to control for acquiescence bias. Each question is short, neutral and assesses a single usability aspect. The scale begins with the most important question regarding the perceived suitability of the method for the given task and context. It is followed by a question assessing the degree of enjoyment produced by the method. They are listed first to elicit a spontaneous, unbiased opinion. Consequently, the established usability constructs efficiency, accuracy and ease of use (Brooke, 1996; Finstad, 2010) are assessed. A total AMUS score is calculated similar to the SUS score (Brooke, 1996, p. 5):

AMUS score=(Q1-1+Q2-1+5-Q3+Q4-1+5-Q5)*5

This calculation scores all questions from zero to four, considering negatively coded questions (Q3 and Q5) by subtracting five and scales it to a maximum score of 100.

After each method has been addressed, we ask for the participant's explicit preference regarding the three access methods using a MC question (Q 23). This is the key question of the survey (RQ 1) and is supposed to deliver a clear discrimination of the methods ('undecided' was included as a choice) after participants reflected on their experience with each method by completing the AMUS questions. Consequently, we ask for the perceived reasons for the explicit preference in an open-ended question (Q 24) to explore and reveal any additional usability factors not captured in the AMUS.

Furthermore, part two included four more Likert scale questions inspired by Othman, Petrie and Power (2011) to control for the possibility that overall negative experiences influence the perception of the different access methods (e.g. positive impact on museum experience, quality of background information, and potential use of Museum Guide app during future visits). A question about problems experienced using the app was included for the same reason. Two questions at the end of the questionnaire asked for desired features and improvements for a mobile guide in general as well as for VR in particular. The demographic questions were attached at the end of the survey to avoid opt-out (SurveyMonkey, 2011) and for formatting reasons.

4.6. DATA ANALYSIS

The collected data was recorded in MS Excel[18]. The data from the survey was combined with the logged data using the session ID that was written on each survey and logged in the device before every participant started the experiment. The collected data was analyzed in Excel (basic descriptive statistics) and SPSS[19] (statistical analysis).

[18] http://office.microsoft.com/en-us/excel/

[19] http://www-01.ibm.com/software/analytics/spss/

5. EXPERIMENT RESULTS

5.1. SAMPLE DESCRIPTION

89 participants (26 in Huis Marseille, 63 in Groninger Museum) took part in the experiment, 48 were females, and 39 were males. Figure 8 shows the age distribution. 19 participants stated not to know much about art, 48 to know the major trends, and 20 to have knowledge of many artists and their work. Prior experiences and attitudes are summarized in Figure 7. 87 participants could imagine mobile apps to be useful in museums, however only three respondents stated to have used mobile apps in museums before themselves. On average, participants used the Museum Guide for 19 minutes (Median 16 minutes, i.e. skewed by a few very long sessions). They accessed 12.1 distinct artworks on average (SD 5.0), but also tried different methods on the same artwork (total average use was 15.1, SD 8.4). VR was used on average 6 (SD 3.85), QR codes 4.3 (SD 3.36), and Keypad 4.7 (SD 3.49) times.

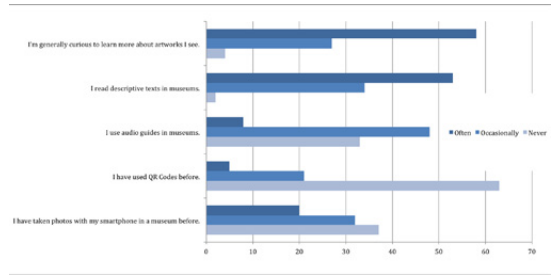


Figure 7: *Visitor Experiences and Attitudes*

Three visitors started the first part of the questionnaire, but opted out before beginning the visit. Their answers were excluded. Two surveys were incomplete (missing several questions of part 2). The incomplete answers were included. Six respondents crossed two options for the preferred method question. Their answer was recoded as 'Undecided'.

5.2. DIFFERENCES BETWEEN MUSEUM SAMPLES

We tested all questions and log data for significant differences between the sample from the Huis Marseille and the Groninger Museum. Overall, the tests showed no significant differences between the samples. Differences were found for individual items, however there were no statistically significant differences for the key questions (usability and preferred access method). Therefore, we can reasonably combine the two samples and continue with a joint analysis. A detailed description of the analysis is below.

Most importantly, we used a chi-square test to check for differences with respect to preferred access methods (Q 23), but no statistically significant differences were found, x^2 (2)= 2.491,p= 0.477. Furthermore, we controlled for differences in perceived usability (Q8-22) using Mann-Whitney tests and again no statistically relevant differences were found for any of the fifteen questions (at significance level a = 0.05).

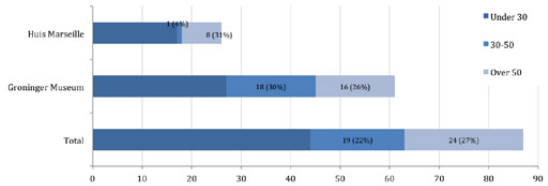


Figure 8: *Age distribution across samples*

In addition, we assessed differences with respect to age, gender, art knowledge, the questions on prior experience of part 1 (Q 1-7) using Chi-square tests and differences regarding the overall experience with the app (Q 26-29) and logged data using Mann-Whitney tests. Statistically significant differences were only found for the age distribution, x^2 (2)= 7.241,p= .027 (see Figure 8 for age distribution). The difference is due to recruiting via social media in the Huis Marseille and the generally older visitors at the Groninger museum. Since no statistically significant differences with respect to questions about preferences between samples (see above) and between age groups when aggregated (see section 5.3) were found, the difference in age composition between samples was not considered for further analysis.

The sample from the Groninger Museum is almost three times bigger than the one from the Huis Marseille, however, the conditions for the nonparametric tests were fulfilled (expected cell frequency for all cells above one for Chi-square test and similarly shaped distributions for Mann-Whitney test; Conover, 1999). Therefore, we assume validity of the statistical analyses and our conclusions.

5.3. RQ 1: DO MUSEUM VISITORS WANT VISUAL RECOGNITION?

Our principal research question was explicitly assessed with Q 23. Figure 9 presents the results as a frequency distribution by preferred access method. Visual Recognition was significantly preferred with 53% (46 participants), 23% preferred the Keypad (20 participants), 14% preferred QR codes (12 participants) and 10% were undecided (9 participants), x^2 (2)= 39.023,p= .000. When excluding 'undecided' participants' 59% chose VR compared to 41% for both alternatives combined.

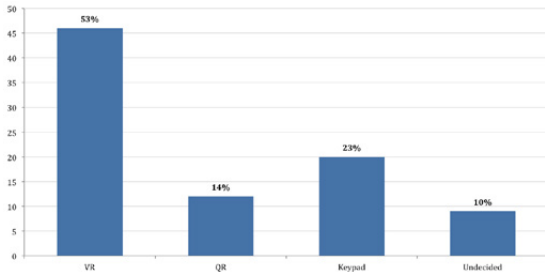


Figure 9: *Explicitly preferred access method of participants*

In addition we related demographic information and prior experiences with the preferences. We conducted Chi-square tests to investigate statistically significant differences between groups in the variable age, gender, art knowledge, and the three prior experience variables use of audio guides, use of QR codes and use of smartphone to take pictures in museums. The prior experience was recoded to binary format (the answers occasionally and often were grouped together). All six Chi-square tests yielded p-values well-above the significance level of .05 (prior experience with audio guides: p=0.767; QR codes: p=0.616; picture-taking in museums: p=0.610), and hence, no statistically significant difference between the groups for any of the variables can be concluded. In Table 4, the participants' preferences are shown as percentages of the group total, i.e. standardized to enable comparison per method controlled for different group sizes. Although not statistically significant (p=0.09), a closer examination of preferences by age group revealed that relative preference for VR increases with age (43% for under 30, 58% for 30-50, and 67% for above 50).

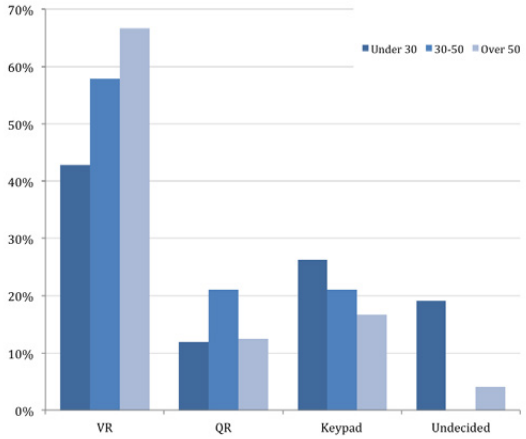


Figure 10: *Preferences by age*

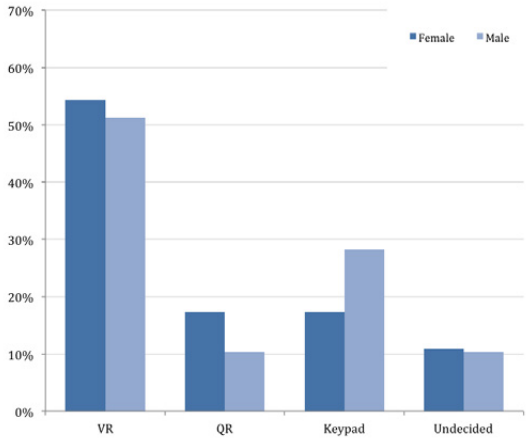


Figure 11: *Preferences by gender*

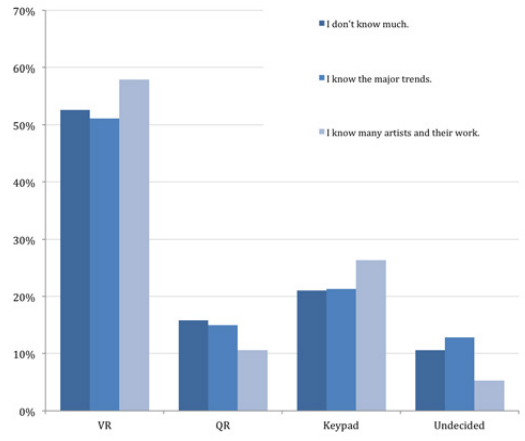


Figure 12: *Preferences by art knowledge*

Table 4: Graphs relating the explicitly preferred access method with demographics and prior experiences of participants

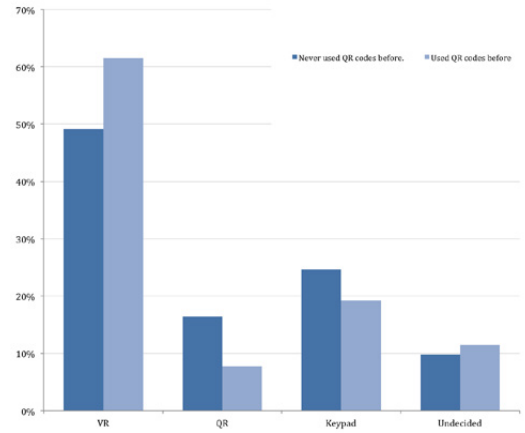


Figure 13: *Preferences by prior experience with QR codes*

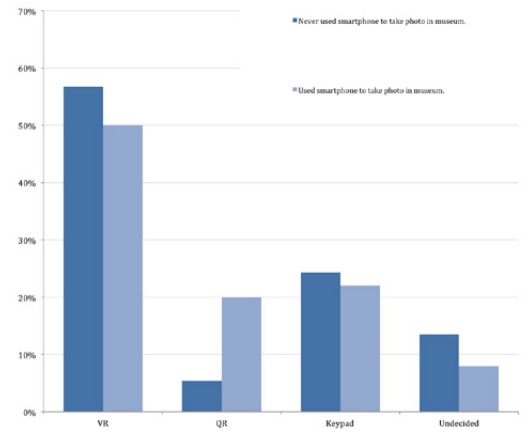


Figure 14: *Preferences by prior experience taking photos with smartphones in museums*

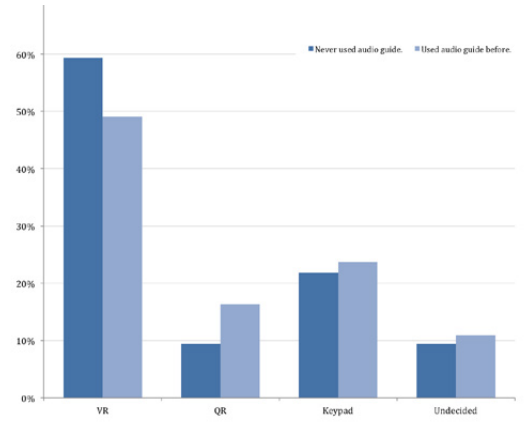


Figure 15: *Preferences by experience with audio guides*

5.4. RQ 2: WHAT ARE THE REASONS FOR VISITOR PREFERENCES?

We attempted to capture this question quantitatively by developing the Access Method Scale Usability Scale (AMUS) and qualitatively by asking participants for the perceived reasons for their preferences.

5.4.1. QUANTITATIVE ASSESSMENT

The average results for the individual usability questions per method are summarized in Figure 16. The total average AMUS score (with equally weighted factors) for VR is 76.3, for QR Codes 67.8, and for Keypad 75.0. Although VR has overall the highest score, the explicit preference for VR (Q 23) is not reflected in the average AMUS. Comparing the preferred method with the highest AMUS per participant, however, reveals correspondence in 60 out of 87 cases (69%). Excluding 'undecided' participants, the highest AMUS and explicit preference coincide with 77% and Pearson Correlation is significant with .661 (N=78). Therefore, on an individual level, the AMUS significantly relates to the explicit preference.

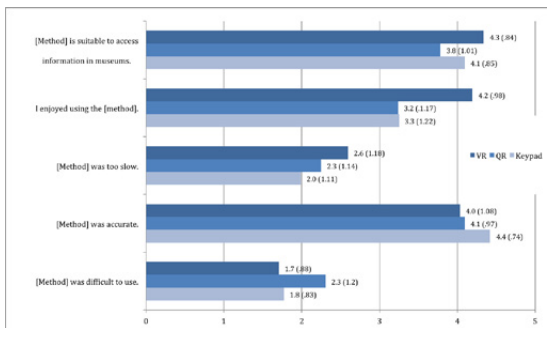


Figure 16: *Mean responses (and standard deviations) to the five items of the AMUS for usability assessment of the three methods.*

We further analyzed differences in the scores for each item between the methods in a repeated measures within-subjects design. An examination of the data revealed outliers (boxplot) and violations of normality (Shapiro-Wilk test). Therefore, the analysis was conducted using the parametric related-samples Friednman's test. Significant differences were found for four of the five factors (but as expected not for total score). Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons to identify differences and their directions as shown in Table 5.

Construct	Significant Difference
1. Suitability	VR was perceived to be significantly more suitable than QR codes (p=0.004)
2. Enjoyment	VR was perceived to be significantly more enjoyable than both QR and Number codes (p←0.000)
3. Speed	VR was perceived to be significantly slower than number codes (p=0.008)
4. Accuracy	No significant differences with Bonferroni correction for type one errors in multiple comparisons.
5. Ease of use	QR codes were perceived to be significantly more difficult to use than both VR and Number codes (p=0.011 and p=0.035 respectively).

Table 5: *Differences between methods in AMUS identified by Friedman's Test and pairwise comparisons.*

5.4.2. QUALITATIVE ASSESSMENT

In addition to the usability constructs included in the AMUS, reasons for the preference were assessed qualitatively in an open-ended question (Q 24) after asking for explicit preference (Q 23). The answers were grouped by preferred method and coherently summarized using emergent categories from recurring answers (Lofland & Lofland, 1995). There was high consistency/similarity across answers facilitating aggregation under key terms. Although not explicitly asked for, several respondents included criticism of the other methods.

For VR (N=46) the most recurring reasons were 'Easy to use' (25 times) and 'Distance' (21 times). Easy to use was associated with attributes such as 'handy', 'intuitive', 'accessible' and 'minimal interaction'. Participants also noted particular benefits for handicapped visitors. 'Distance' referred to the ability to obtain information without having to move (closer). The benefits of keeping the distance were also emphasized for use in crowded museums. Additionally, distance was often mentioned together with 'interactive with artwork' and 'keeping attention on the artwork' (6 times). Further recurring reasons were summarized as 'comparably accurate and fast' (8 times) and fun/enjoyable (6 times). Criticism included slow speed, short range, and dependence on many factors (glass covers, frames and phone memory).

The most occurring reasons for preferring QR codes (N=12) were its speed (7 times) and ease of use (4 times). Moreover, 'fun', 'accuracy', 'useful feedback' and 'low (hardware) requirements' as well as the possibility to step aside and not to be required to stand in front of the artwork were mentioned. Criticism included 'ugly', 'short distance' and potential problems in crowded spaces.

Answers provided by participants that preferred number codes (N=20) mentioned 'speed' and flexibility (both 7 times) and 'distance' (5 times) as their main reasons. 'Flexibility' comprises 'all angles', 'independence', 'no aiming/pointing required', 'no clear view required', 'good when you want to sit' and 'unobtrusive'. Additional reasons entailed 'easy to use' (4 times, mentioning suitability for groups), 'accurate', 'interactive' and 'simple and useful'. Criticism included 'less fun', 'old-fashioned' and 'too much user input'.

The qualitative assessment also revealed diverging perceptions about key aspects, despite the overall trends described and discussed above. While the majority of participants found that VR performed well, some perceived VR to be deficient regarding recognition from various angles, distances, from close-up details and when other visitors blocked the view in crowded spaces (often only a hypothetical scenario absent in the experiment). While some users provided enthusiastic remarks about VR ("putting the smart in the smartphone"), one participant for example also noted that VR used by other visitors was distractive and 'annoying'. Contrasting perceptions were also provided regarding the content (length of text, audio versus video).

5.5. FURTHER FINDINGS

Twenty-four participants (27%) indicated experiencing some sort of problem during the experiment. The most occurring problem 'No recognition with VR' (6 times) was only reported about two paintings at the Groninger Museum (problems were related to interference with elaborate golden frames). The automatic stand-by screen after 30 seconds (4 times) caused the audio playback to stop (4 times). Users reported problems getting back to the app from the stand-by screen and after accidentally exiting the app (4 times). Four users reported problems navigating back within the app, because they did not see the built-in back-button (by default button is not illuminated in Samsung Galaxy S3; design following Android UI guidelines). After feedback from the first experiment, the stand-by mode was disabled and the back-button was permanently lit. Two participants wearing glasses reported difficulties, because they had to take their glasses on and off to switch between looking at the artwork and the text on the screen. They mentioned the audio commentary to be especially useful.

To avoid these problems significantly influencing user perceptions of access methods, we additionally controlled for overall user satisfaction using the app through four questions. The results are presented in Figure 17. The differences in answers separated by preferred access method are insignificant (0.2 SD) and overall satisfaction is high (average for all four questions is 4.05). Hence, problems using the app should not have influenced perception of methods significantly.

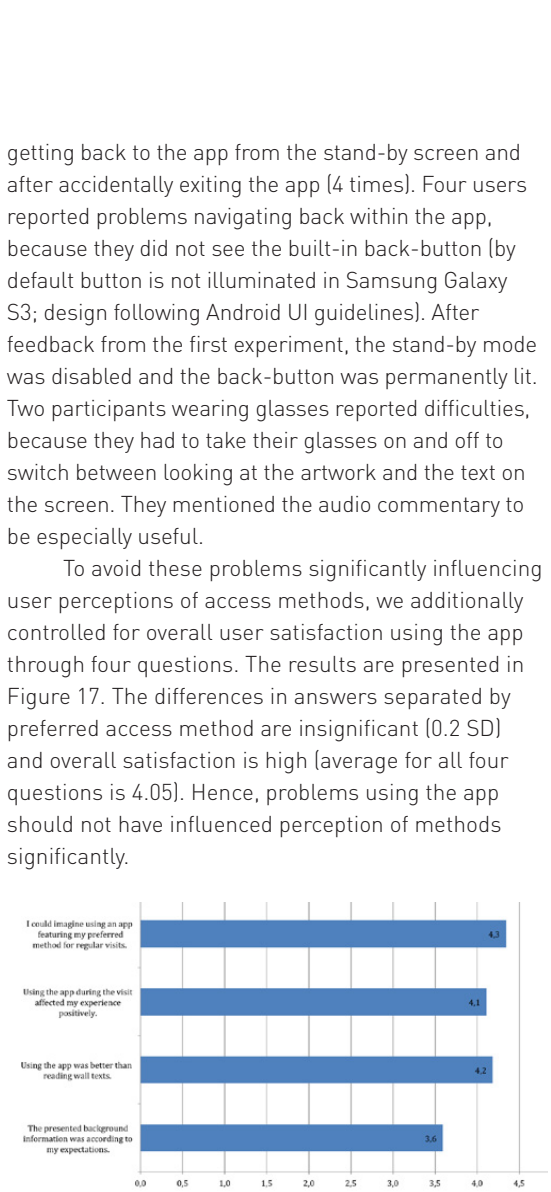


Figure 17: *Mean responses (and standard deviations) for questions assessing the overall experience with the Museum Guide.*

Question 30 assessed what other features participants would like to see in a mobile guide. More 'Specific information about artworks' was by far the most frequent answer (21 times), followed by 'layered content' (13 times). Other frequently mentioned aspects were links to 'related artworks', a 'map' feature, 'more languages' (each 7 times), and a 'save for later'-functionality (6 times). The most urgent improvements to the VR method identified by participants (Q 31) were faster recognition (8 times) and better recognition from angles (5 times).

6. DISCUSSION

Following the hypothesis that VR represents a more natural, unobtrusive way to access background information on artworks compared to QR codes and number codes, we investigated visitors' perception of VR (RQ 1) and the reasons for preferring one of the three access methods (RQ 2). We implemented the three access methods in a Museum Guide app and evaluated them in a field experiment with 89 participants in two museums.

6.1. RQ 1: DO VISITORS WANT VISUAL RECOGNITION?

The answer is surprisingly clear: The absolute majority of participants preferred VR (53%, and 59% when excluding 'undecided'), while both alternatives together were only preferred by 37% (Number codes 23%, QR codes only 14%, 9% were undecided). The observed preferences were consistent across different visitor groups, museums and art genres (no sig. associations found). The results provide evidence that the popularity of VR among researchers and museum professionals found in the literature review is justified by user acceptance: When visitors have the choice, a majority seems to want VR. Remarkably, QR codes was the least preferred method, despite their current popularity (American Alliance of Museums, 2012). VR and QR codes are both considered 'new' methods, similar in that they use the smartphone camera to access information. However, while VR directly interacts with the artwork, QR codes introduce a machine-readable matrix-barcode between the user and the artwork. The difference in preferences of almost 40% could be related to this distinction. Participants might not perceive VR as a 'technologically-sophisticated', but rather as a 'natural' method following familiar photo-taking patterns (See Figure 1 and Appendix D). VR utilizes technology to remove barriers (such as looking for small codes) and focuses attention on the artwork. In contrast, the technical aspect of QR codes might be more consciously perceived than for VR and this appears to detract from the 'naturalness' of art appreciation.

Contrary to our expectation based on technological affinity, older visitors actually preferred VR more strongly than younger visitors (43% for under thirty, 58% for thirty to fifty, and 67% for over fifty). One reason might be that older visitors are less

critical and more easily impressed, because they are potentially less familiar with the state-of-the art in mobile technology than younger visitors, which use that knowledge as a benchmark. Other possible reasons could be that minimal required input and movement, as well as not having to look for (small) codes are more important factors for older visitors. These considerations might also be relevant to understand the perceived helpfulness/convenience of VR for handicapped visitors and visitors with (slight) visual disability or impairment (e.g. cataracts and astigmatism).

Furthermore, prior experience did not lead to increased preference for the related access method. In fact, participants that stated prior experience with QR codes were less likely to prefer QR codes (8% with experience versus 16% without experience) and more likely to prefer VR (62% with experience versus 47% without experience). Possible reasons might have been negative preconceived opinions about QR codes and therefore a higher awareness for the benefits of VR (to eliminate the need for codes) and simply that they might not have enjoyed QR codes in their previous use. Participants that were not familiar with them might on the other hand have been surprised by the speed of QR codes. Similarly, participants that had taken photos in museums before (expected to result in higher preference for VR based on familiarity) were less likely to prefer VR than those without experience (48% with prior experience versus 57% of participants that had not taken photos in museums before). One possible reason might be that participants did not associate the pointing movement of VR with photo shooting, since the characteristic photo shooting/ camera still shot function was not implemented in the prototype (see discussion in 3.4). Another reason might have been that phrasing of the question was too narrow ('taking photos with a smartphone in museums', instead of simply 'taking pictures in museums').

6.2. RQ 2: WHAT ARE THE REASONS FOR VISITOR PREFERENCES?

The analysis of the AMUS scores revealed enjoyment, ease of use and suitability as discriminating factors explaining the observed preferences. Adequate speed and accuracy seem to be necessary factors, but they do not seem to have significant discriminatory power at least for the relatively high performance level of our methods. Overall AMUS scores correctly predicted preferences for 77% of participants (excluding 'undecided', 0.66 sig. positive correlation). The qualitative assessment revealed 'distance' (that the user is able to maintain from the artwork using a method) as an additional critical factor determining preferences (most frequently named reason, 21 times for VR, 5 times for Keypad). Distance, enjoyment, and ease of use can be considered to contribute to a natural, unobtrusive interaction. Since VR scored highest on enjoyment and ease of use and was most frequently associated with distance, the results also support our hypothesis that VR is preferred, because it facilitates a more natural, unobtrusive interaction with the artworks.

Ease of use appears to be a decisive factor for participants as it was stated frequently as a reason for all three methods including QR codes (VR: 25 times, QR: 5 times, Number codes: 4 times). However, individual participants seem to have diverging perceptions about which method was easy to use, because overall the AMUS analysis showed that QR codes were perceived as more difficult to use (statistically significant, VR 1.7, QR 1.8, Keypad 2.3). This is surprising; given the simplicity of using QR codes experienced during lab tests and might indicate usability issues (see discussion of speed).

Suitability scores reflect the low approval of QR codes and the high preference for VR. QR codes were perceived to be the least suitable method for use in museums (VR 4.3, Keypad 4.1, QR 3.8; statistically significant difference to VR, p=0.004). This perception presents a noteworthy contrast to the trends reported by the American Association of Museums and the British Museums Associations (2012; 2012) that see QR codes to be the most prominent mobile feature in museums in that year.

Enjoyment: Participants clearly enjoyed using VR most (VR 4.2, QR 3.2, Keypad 3.3; statistically significant difference to both, p←0.000). Enjoyment was the factor with the clearest distinction between VR and the other methods and might have an important role in explaining the surprisingly strong explicit preference for VR (Q 23). Participants described VR as 'sexy', 'cool', 'funny [that] the smartphone sees the painting' and 'it really puts smart into the smartphone'. VR was also used most often (VR 6 times, QR 4.3 times, Keypad 4.7 times), reflecting the high 'enjoyment' factor of the method.

Speed and Accuracy seem to lose differentiating significance when performance is within an adequate range. VR was perceived to be the slowest (coinciding with lab tests) and least accurate, but this was not reflected in the overall preference for VR (Figure 9). Although VR scored last for both factors, the similarity of the scores among the three methods confirms the maturity of the VR technology for production use (statistically significant difference only for speed between VR and Keypad). It also indicates that an exclusive focus on accuracy and speed found in the previous literature might have become insufficient for assessing user perceptions of VR and possibly mobile technology in general. Capturing usability indeed seems to require considering all attributes of the definition (see 2.3). Nevertheless, speed is important: when explicitly asked for areas of improvement, participants most frequently stated recognition speed (8 times). Surprisingly, QR codes were perceived to be slower than Keypad (contrary to lab tests). This might be related to scanning problems (holding the camera too close to the QR code or pointing at it from an angle), which have been reported. An instruction-text might have mediated this problem and improved perceived speed of the QR code method (although users did not criticize the speed of QR codes).

Distance, in a way, is the most intriguing factor, firstly, it is because participants independently suggested it as their main reason in the open-ended answer section of the survey, and secondly, because it clearly relates to the attributes 'natural and unobtrusive interaction' formulated in the hypothesis. Most importantly however, it might explain the significant difference in preferences between VR and both Keypad and QR codes, although the argumentation cannot be based on reliable quantitative results. The setup illustration (Figure 6) showed that the artwork itself is clearly visible from the distance that the photo is taken and hence recognizable via VR; in contrast both QR and number codes have to be shown in detail-view to make them identifiable. VR allows for a more natural distance between the visitor and the artwork and does not require the visitor moving out of her way to obtain information. One participant (female, under thirty) vividly articulated this relationship: "You can get information from a longer distance and mentally, there's a smaller distance between the information and the painting." This also highlights the relationship between 'distance' and 'engagement with artwork' (6 times) found in the responses. Distance was also stated as a reason for number codes, however. While this seems valid for our experiment (large, highlighted labels, no overly crowded rooms), Figure 18 points out the practical limitations for identifying number codes from a distance.

Figure 18: *Number codes in practice. Top left - the number code used during the experiment compared to the code normally used by the Groninger Museum; top right - a crowded, poorly illuminated gallery at the Musée d'Orsay (Paris, April 2013); bottom row – two artworks from the 'Vincent' exhibition at the Hermitage (Amsterdam, April 2013).*

The photos exemplify that in practice number codes can frequently not be identified from a distance because they are too small (top left and bottom row), hidden within blocks of information (top left) or not visible due to poor illumination and other visitors blocking access (top right and bottom row). Therefore, the potential of number codes regarding the factor distance is often limited in practice. In addition, they still require a shift of attention away from the artwork to find and identify the code. In contrast VR is inherently a distance-based access method, which is reflected in the consistent reoccurrence of distance as a reason for VR. 'Distance' seems to provide the most complete explanation for the overall preference ranking of the three methods as it predicts the strong preference of VR over both alternatives, while it also provides reasons why number codes were preferred over QR codes in the experiment.

Importance of situated context, technical progress and validity: Our findings differ from Möller et al. (2012), who found that barcodes (similar to

QR codes) were significantly preferred over VR in a medicine packaging recognition task and identified speed as the critical factor. We see three plausible reasons for the difference. Most importantly, the situated context (Nielsen et al., 2006, Pedell et al., 2003): Distance, which we identified as a critical factor for the museum context, is irrelevant (and potentially detrimental) for recognizing small objects based on package design. Secondly, technological progress: Our implementation of VR was 12 seconds faster (4.2 versus 16.4 seconds; Möller et al., 2012, p. 8) and as suggested above, speed might lose its differentiating significance within an adequate range. Finally, validity: Möller et al.'s small convenience sample might raise questions regarding the validity of their results (see 6.3 for limitations of this study).

6.3. LIMITATIONS

Sample composition

One third of the participants were not regularly visiting the museum, but specifically recruited for the experiment either from the street or through social media. While this might have introduced limitations to validity, we attempted to mediate and control them as much as possible via a rigorous experiment setup, a large sample size (Schmettow, 2012), and most importantly via thoroughly testing for differences between the samples.

Rejections and voluntary participation bias

We did not keep a quantitative record of how many visitors rejected participating (at the Groninger Museum). Therefore, we cannot provide a reliable rejection-quota. In general, it was easy to recruit participants for all sessions. Nevertheless, a significant part of visitors approached rejected participation. The five reasons we identified: insecurity of being addressed by foreigner in English, lack of time, group visits, lack of confidence to use English guide, no interest in additional information or using a mobile guide. Therefore, our sampling procedure likely introduced a voluntary participation bias. This seems acceptable, however, since we only aim to make inferences about those museum visitors interested in additional information, not necessarily the overall visitor population.

Negative impact of general problems encountered

The survey revealed that twenty-four participants (27%) encountered some sort of problem using the Museum Guide app. A large number of participants encountering general problems (e.g. crash of the app, reported three times) might reflect negatively on their perception of individual methods as proposed by Kuflik et al. (2011, p. 11:15). For example, one participant remarked that VR would not offer an audio commentary for two artworks, although this was a problem encountered for QR and number codes as well. However, overall satisfaction with the Museum Guide app (Q 29: 4.3 average, Q 27: 4.1 average) and extensive usage (19 minutes average, 15 times used) do not indicate that these problems significantly influenced user perceptions.

6.4. PRACTICAL IMPLICATIONS

Implementing larger databases with VR

The lab tests showed that matching times increase significantly with database size. Current smartphones and visual recognition techniques are most likely not capable of delivering the required performance for actual museum databases of several hundred artworks. The currently available alternative is to use a client-server architecture (e.g. Ruf et al., 2010). This requires a fast, reliable Internet connection provided for by either the museum (WIFI, requires infrastructure) or the visitor (3G/4G, may incur high roaming costs). While server-side processing makes large databases feasible and potentially allows more lightweight apps (retrieve content form server on-demand), it also introduces connectivity risks that can deteriorate performance. Potential improvements could be achieved by splitting the recognition task in phone-based feature extraction (independent of database size) and server-side descriptor matching (reducing data load on network and potentially increasing speed). In the future, a mixed approach combining VR with location awareness (via GPS or WIFI) could be used to limit the set of potential reference images based on the user's location, similar to the approach of current outdoor augmented reality apps. This would reduce computational requirements of the matching process and might make phone-based VR feasible even for larger databases. Further exploration of these options was out of scope for this research, but would constitute relevant follow up research.

New content and interaction formats with VR

Content is crucial – that is what participants most frequently stated in their feedback (Q 30). In particular, participants asked for more specific information (21 times), more structured/layered information (13 times), related artworks recommendations, more languages, map/floor plan (7 times each) and 'save for later'-functionality (6 times). VR offers much unexplored potential to embed corresponding new content and interaction formats. For example: recognition of details of a painting in order to retrieve specific information; camera functionality that could make it more engaging to get back to 'saved information' about specific artworks later on; virtual reality and augmented reality could be embedded for games, interactive content or to provide individualized guidance through the museum. Although the possibilities are abundant, the most important benefit might be that it places the emotional experience in the center: VR allows visitors to freely wander around and access information based on aesthetical excitement, instead of predefined routes. However, an investigation of the relations between content type and access method was outside the scope of this research. Given the potential of VR and the importance of good content, this relationship forms another important future research area.

7. CONCLUSIONS

Mobile museum guides have significant, untapped potential

Our findings show that museums have a significant, largely untapped potential to improve visitors' experience through mobile museum guides. Most visitors want specific, high-quality background information (96%) and even before ever having used a smartphone in a museum (3%), 98% thought mobile apps could be useful to obtain this information. The vast majority of participants immediately recognized the potential benefits of museum guides after the experiment. Using this particular prototype app, 78% stated it affected their experience positively and 87% would be interested to use an app featuring their preferred method for regular visits ('agree' and 'strongly agree' combined). As smartphone ownership continues to increase rapidly, mobile museum apps have the potential to substitute audio guides and become mainstream in museums.

Visitors want visual recognition

53% of all participants would use VR if they had the choice. This is significantly more than the 37% of both alternative methods combined (23% preferred Keypad and 14% QR codes). The hypothesis that VR allows for more natural, unobtrusive interaction was confirmed. The main reasons for choosing VR were its ease of use, enjoyment of use, and the distance it allows one to maintain from the artwork. These factors should be considered in implementing VR and other access methods in mobile museum guides.

Combination of VR and Keypad at present, VR in the future

This research demonstrated the efficacy of VR for production use; it also presented strong evidence for VR as the preferred access method and identified explanatory reasons. However, VR still has significant potential of improvement regarding speed and accuracy. Furthermore, despite the majority that prefers VR, the research showed that a sizable minority prefers number codes (almost one quarter). Hence, in the short-term, we recommend introducing VR to visitors by offering museum guide apps that provide a choice between VR and another method. Based on the analysis of the AMUS scores and the stated user preferences (23%), the Keypad method seems to be a suitable second choice for current museum guide projects. The only reliably significant difference was found regarding the enjoyment of use provided by the methods. Arguably, there is also a significant difference with respect to distance (as discussed in 6.2), however we did not obtain reliable quantitative evidence for this factor.

Providing the choice of these two methods would assure that users get access to information even if VR fails to recognize an object (e.g. under difficult conditions or considering 3D objects). Most importantly, a dual solution would mediate the consistency requirement (provide information for all artworks), since the Keypad method would introduce physical number code labels that can serve as an indicator for available content. Database and Content Management Systems (DBMS, CMS) should therefore be capable of supporting various access methods and in particular these two and automatically generate corresponding guide apps.

In the medium and long run, museums should focus on VR as the primary access methods. We

identified several advantages of VR that are arguably based on fundamental differences that other methods do not have (i.e. distance-based) and have found these advantages to already be reflected in user perceptions. On the other hand, we did not identify any systematic advantages of QR or number codes. Factors like speed and accuracy are likely to improve further in the future for VR as well. Therefore, focusing on VR would require the provision of more consistent, high-quality information on all artworks. While it would increase workload for museums in the short-run, it will improve the visitors' experience significantly (considering the identified importance of more specific information). VR also promises benefits for an increasingly older visitor population (with handicaps such as visual impairments). Furthermore, VR is a modern, 'sexy' method suitable for all age groups. The appeal of VR and the abundant opportunities to link content might also make it easier to attract funding for developing new projects in the future.

REFERENCES

Abowd, G. D., & Mynatt, E. D. (2000). Charting past, present, and future research in ubiquitous computing. ***ACM Transactions on Computer-Human Interaction, 7***(1), 29–58. doi:10.1145/344949.344988

Alahi, A., Ortiz, R., & Vandergheynst, P. (2012). FREAK : Fast Retina Keypoint. ***2012 IEEE Conference on Computer Vision and Pattern Recognition,*** 510–517. doi:10.1109/CVPR.2012.6247715

Albertini, A., Brunelli, R., Stock, O., & Zancanaro, M. (2005). Communicating user's focus of attention by image processing as input for a mobile museum guide. ***Proceedings of the 10th international conference on Intelligent user interfaces - IUI '05*** (p. 299). New York, New York, USA: ACM Press. doi:10.1145/1040830.1040905

Alfandari, A. (2013). Mobile Strategy & Innovation @ the Louvre. ***Museums & Mobile 2013.*** Retrieved from http://www.museums-mobile.org/program-details-mm6/

American Alliance of Museums. (2012). ***AAM: Mobile in Museums Study 2012*** (pp. 1–61). Retrieved from https://aam-us.org/docs/research/mobilemuseums2012-(aam).pdf

American Association of Museums. (2011). AAM: 2011 Mobile Technology Survey.

Andreatta, C., & Leonardi, F. (2006). Appearance Based Paintings Recognition For a Mobile Museum Guide. ***International Conference on Computer Vision Theory and Applications, VISAPP 2006.*** Retrieved from http://tev.fbk.eu/TeV/Publications/AndLeo_VISAPP06.pdf

Bay, H., Fasel, B., & Gool, L. Van. (2006). Interactive museum guide: Fast and robust recognition of museum objects. ***Proceedings of the first international workshop on mobile vision.*** Graz, Austr. Retrieved from http://eprints.pascal-network.org/archive/00002403/

Brooke, J. (1996). SUS-A quick and dirty usability scale. ***Usability evaluation in industry*** (pp. 189–194). Taylor and Francis. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:SUS+-+A+quick+and+dirty+usability+scale#0

Cairns, S. (2012). How to Win an Art Prize Without Making a Thing: QR codes, Classifications and Controversy. ***Museums and the Web 2012.*** Retrieved from http://www.museumsandtheweb.com/mw2012/papers/how_to_win_an_art_prize_without_making_a_thing

Campbell, T. P. (2011). The Metropolitan Museum of Art - Google Goggles. Retrieved April 10, 2013, from http://www.metmuseum.org/about-the-museum/now-at-the-met/from-the-director/2011/google-goggles

Conover, J. V. (1999). ***Practical Nonparametric Statistics*** (Third Edit., pp. 1–592). New York, New York, USA: John Wiley & Sons, Inc. Retrieved from http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471160687.html

Damala, A. (2006). Evaluation strategies for mobile museum guides: a theoretical framework. ***3rd International Conference ...,*** (Icom 2001), 1–9. Retrieved from http://areti.freewebspace.com/pdf_files/avicom2006.pdf

Economou, M., & Meintani, E. (2011). Promising beginnings? Evaluating museum mobile phone apps. In L. Ciolfi, K. Scott, & S. Barbieri (Eds.), ***Rethinking Technology in Museums 2011***. Emerging experiences (pp. 87–101). Limerick, Ireland.

Emmanouilidis, C., Koutsiamanis, R., & Tasidou, A. (2013). Mobile guides: Taxonomy of architectures, context awareness, technologies and applications. ***Journal of Network and Computer Applications, 36,*** 103–125. doi:http://dx.doi.org/10.1016/j.jnca.2012.04.007

Finstad, K. (2010). The Usability Metric for User Experience. ***Interacting with Computers, 22***(5), 323–327. doi:10.1016/j.intcom.2010.04.004

Föckler, P., Zeidler, T., Brombach, B., Bruns, E., & Bimber, O. (2005). PhoneGuide: museum guidance supported by on-device object recognition on mobile phones. ***Proceedings of the 4th international conference on Mobile and ubiquitous multimedia - MUM '05*** (p. 3). New York, New York, USA: ACM Press. doi:10.1145/1149488.1149490

Germann, M. (2006). ***Object Recognition with Mobile Phones. semester thesis, Computer Vision***

Laboratory, ... ETH Zürich, Zurich. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.100.6376&rep=rep1&type=pdf

Google, & Ipsos OTX. (2011). ***The Mobile Movement*** (pp. 1–39). Retrieved from http://www.google.com/think/research-studies/the-mobile-movement.html

Groninger Museum. (2010). GM Collector. Retrieved March 15, 2013, from http://www.groningermuseum.nl/en/gmcollector

Harris, C., & Stephens, M. (1988). A combined corner and edge detector. In M. M. Matthews (Ed.), ***Alvey vision conference*** (Vol. 15, pp. 147–151). Manchester, UK. doi:10.1007/s10646-010-0463-6
Heinly, J., Dunn, E., & Frahm, J.-M. (2012). Comparative evaluation of binary features. ***Computer Vision – ECCV 2012*** (Vol. Computer V, pp. 759–773). Springer Berlin Heidelberg. doi:10.1007/978-3-642-33709-3_54

IDC, & Facebook. (2013). ***Always Connected - How Smartphones and Social Keep Us Engaged.*** Retrieved from https://fb-public.box.com/s/3iq5x6uwnqtq7ki4q8wk

ISO. (1998). ISO 9241-11. Retrieved April 15, 2013, from http://www.usabilitynet.org/tools/r_international.htm

Jang, Y., & Woo, W. (2011). Stroke-based semi-automatic region of interest detection algorithm for in-situ painting recognition. ***Proceedings of the 2011 international conference on Virtual and mixed reality: systems and applications - Volume Part II*** (pp. 167–176). Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-22024-1_19

Jimenez Pazmino, P., & Lyons, L. (2011). An exploratory study of input modalities for mobile devices used with museum exhibits. ***Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*** (p. 895). New York, New York, USA: ACM Press. doi:10.1145/1978942.1979075

Kawaji, H., Hatada, K., Yamasaki, T., & Aizawa, K. (2010). Image-based indoor positioning system. ***Proceedings of the 1st ACM international workshop on Multimodal pervasive video analysis - MPVA '10*** (p. 1). New York, New York, USA: ACM Press. doi:10.1145/1878039.1878041

Kenteris, M., Gavalas, D., & Economou, D. (2010). Electronic mobile guides: a survey. ***Personal and Ubiquitous Computing, 15***(1), 97–111. doi:10.1007/s00779-010-0295-7

Khvedchenia, I. (2012). Comparison of the OpenCV's feature detection algorithms – II. Retrieved March 15, 2013, from http://computer-vision-talks.com/2011/07/comparison-of-the-opencvs-feature-detection-algorithms-ii/

Kuflik, T., Stock, O., Zancanaro, M., Gorfinkel, A., Jbara, S., Kats, S., Sheidin, J., et al. (2011). A visitor's guide in an active museum. ***Journal on Computing and Cultural Heritage, 3***(3), 1–25. doi:10.1145/1921614.1921618

Laan, L. van der. (2013). KUNST OP 'T KIEKJE. ***N8 Blog***. Retrieved May 16, 2013, from http://blog.n8.nl/2013/05/16/kunst-op-'t-kiekje/

Lee, S., & Koubek, R. J. (2010). Understanding user preferences based on usability and aesthetics before and after actual use. ***Interacting with Computers, 22***(6), 530–543. doi:10.1016/j.intcom.2010.05.002

Leighton, D. (2007). In the frame: investigating the use of mobile phone photography in museums. ***International Journal of Nonprofit and Voluntary Sector Marketing, 12***(4), 308–319. doi:10.1002/nvsm.320

Leutenegger, S., Chli, M., & Siegwart, R. Y. BRISK: Binary Robust invariant scalable keypoints. (A. Abe & R. Oehlmann, Eds.), 2011 International Conference on Computer Vision 2548–2555 (2011). IEEE. doi:10.1109/ICCV.2011.6126542

Lofland, J., & Lofland, L. H. (1995). ***Analyzing Social Settings: A Guide to Qualitative Observation and Analysis. The Wadsworth Series in Analytic Ethnography*** (Vol. 2nd, p. 282). Wadsworth. Retrieved from http://books.google.com/books?id=zYPFQgAACAAJ&pgis=1

Long, S., Kooper, R., Abowd, G. D., & Atkeson, C. G. (1996). Rapid Prototyping of Mobile Context-Aware Applications : The Cyberguide Case Study. ***Proceedings of the 2nd ACM International Conference on Mobile Computing and Networking (MobiCom '96).***

Lowe, D. G. (1999). Object recognition from local scale-invariant features. (J. Tsotsos, Ed.) ***Proceedings of the Seventh IEEE International Conference on Computer Vision, 2***([8), 1150–1157 vol.2. doi:10.1109/ICCV.1999.790410

McKenzie, B., & Poole, N. (2011). ***Mapping the use of digital technologies in the heritage sector. authoring.hlf.org.uk.*** Retrieved from www.flowassociates.com

Miksik, O., & Mikolajczyk, K. (2012). Evaluation of Local Detectors and Descriptors for Fast Feature Matching. ***International Conference on Pattern Recognition ICPR.*** IAPR.

Möller, A., Diewald, S., Roalter, L., & Kranz, M. (2012). MobiMed: : Comparing Object Identification Techniques on Smartphones. ***Proceedings of the 7th Nordic Conference on Human-Computer Interaction Making Sense Through Design - NordiCHI '12*** (p. 31). New York, New York, USA: ACM Press. doi:10.1145/2399016.2399022

Monod, E., & Klein, H. (2005). A phenomenological evaluation framework for cultural heritage interpretation: From e-HS to Heidegger's historicity. ***AMCIS 2005 Proceedings, 1***(1). Retrieved from http://aisel.aisnet.org/amcis2005/394/

Museums Association. (2012). ***Museums Association: Mobile Survey 2012*** (pp. 1–29). Retrieved from http://www.museumsassociation.org/asset_arena/8/91/13/731198/v0_master.pdf

Nielsen, C. M., Overgaard, M., Pedersen, M. B., Stage, J., & Stenild, S. (2006). It's worth the hassle! The Added Value of Evaluating the Usability of Mobile Systems in the Field. ***Proceedings of the 4th Nordic conference on Human-computer interaction changing roles - NordiCHI '06*** (pp. 272–280). New York, New York, USA: ACM Press. doi:10.1145/1182475.1182504

Othman, M., Petrie, H., & Power, C. (2011). Engaging visitors in museums with technology: scales for the measurement of visitor and multimedia guide experience. ***Proceedings of the 13th IFIP TC 13 international conference on Human-computer interaction*** (Vol. IV, pp. 92–99). Lisbon, Portugal: Springer-Verlag. Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-23768-3_8

Pallud, J., & Monod, E. (2010). User experience of museum technologies: the phenomenological scales. ***European Journal of Information Systems, 19***(5), 562–580. doi:10.1057/ejis.2010.37

Pedell, S., Graham, C., Kjeldskov, J., & Davies, J. (2003). Mobile Evaluation: What the Metadata and the data told us. In S. Viller & P. Wyeth (Eds.), ***Proceedings of the 2003 Australasian Computer Human Interaction Conference (OzCHI 2003)*** (pp. 96–105). Brisbane, Queensland. Retrieved from http://people.cs.aau.dk/~jesper/pdf/conferences/Kjeldskov-C17.pdf

Poria, Y., Biran, A., & Reichel, A. (2009). Visitors' Preferences for Interpretation at Heritage Sites. ***Journal of Travel Research, 48***(1), 92–105. doi:10.1177/0047287508328657

Rekimoto, J., & Nagao, K. (1995). The world through the computer. ***Proceedings of the 8th annual ACM symposium on User interface and software technology - UIST '95*** (pp. 29–36). New York, New York, USA: ACM Press. doi:10.1145/215585.215639

Rosten, E., & Drummond, T. (2006). Machine learning for high-speed corner detection. (Aleš Leonardis Horst Bischof & A. Pinz, Eds.)***Machine Learning, 1***(1), 1–14. doi:10.1007/11744023_34

Rublee, E., Rabaud, V., Konolige, K., & Bradski, G. (2011). ORB: An efficient alternative to SIFT or SURF. 2011 ***International Conference on Computer Vision*** (pp. 2564–2571). IEEE. doi:10.1109/ICCV.2011.6126544

Ruf, B., & Detyniecki, M. (2009). Identifying Paintings in Museum Galleries Using Camera Mobile Phones. ***Proceedings of the Singaporean-French Ipal Symposium 2009 - SinFra'09*** (pp. 125–134). Singapore: World Scientific Publishing Co. Pte. Ltd. doi:10.1142/9789814277563_0013

Ruf, B., Kokiopoulou, E., & Detyniecki, M. (2010). ***Mobile Museum Guide Based on Fast SIFT Recognition.***

(M. Detyniecki, U. Leiner, & A. Nürnberger, Eds.) ***Adaptive Multimedia Retrieval.*** ... (Vol. 5811, pp. 170–183). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-14758-6

Schmettow, M. (2012). Sample size in usability studies. ***Communications of the ACM, 55***(4), 64. doi:10.1145/2133806.2133824

Sonderegger, A., & Sauer, J. (2010). The influence of design aesthetics in usability testing: effects on user performance and perceived usability. ***Applied ergonomics, 41***(3), 403–10. doi:10.1016/j.apergo.2009.09.002

SurveyMonkey. (2011). ***Smart Survey Design.*** Austin, Texas. Retrieved from http://s3.amazonaws.com/SurveyMonkeyFiles/SmartSurvey.pdf

Tallon, L. (2013). Mobile Strategy in 2013: ***An Analysis of the Annual Museums & Mobile Survey.*** Retrieved from http://www.museums-mobile.org/survey/

Tractinsky, N., Katz, A. ., & Ikar, D. (2000). What is beautiful is usable. ***Interacting with Computers, 13***(2), 127–145. doi:10.1016/S0953-5438(00)00031-X

Tuch, A. N., Roth, S. P., Hornbæk, K., Opwis, K., & Bargas-Avila, J. A. (2012). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. ***Computers in Human Behavior, 28***(May 2012), 1–26. doi:10.1016/j.chb.2012.03.024

V&A. (2013). ***Understanding the Mobile V & A Visitor: Autumn 2012*** (pp. 1–30).

Winesmith, K. (2013). MCA Insight smart phone app. ***Museums & Mobile 2013*** (pp. 1–34). Retrieved from http://www.slideshare.net/drkeir/keir-winesmithmmpresentationwithannoctations

Xu, Y., Spasojevic, M., Gao, J., & Jacob, M. (2008). Designing a vision-based mobile interface for in-store shopping. ***Proceedings of the 5th Nordic conference on Human-computer interaction building bridges - NordiCHI '08*** (p. 393). New York, New York, USA: ACM Press. doi:10.1145/1463160.1463203

APPENDIX A – QUESTIONNAIRE

NUMBERING OF QUESTIONS WAS ADDED AFTERWARDS FOR BETTER REFERENCE

Dear Participant,

What is the best way to get background information on artworks when you visit a museum? Your participation in this experiment will help to answer this question. The experiment will involve using a smartphone app featuring three methods to access background information on artworks: Visual Recognition, QR Codes and Number Codes. We will demonstrate and explain the three access methods and discuss any questions before you start the experiment. The total duration of the experiment will be approximately 20 minutes.

Instructions:

1. Please fill out part 1 of the questionnaire. There is no expected or right answer.
2. Visit the galleries and use the 'Museum Guide' app to access background information on the artworks. Try each of the three access methods once in the beginning (1x Visual Recognition, 1x QR Codes and 1x Number Codes). You may choose for what artworks and in which order to try the methods. You can 'remember' artworks you liked using the 'star'-button.
3. After using each of the methods once, please use the app **at least** three more times. You are free to get information on all artworks in the galleries and you can choose which access methods to use.
4. After visiting the galleries and returning the smartphone, please fill out part 2 of the questionnaire

By participating in the experiment you agree that we record anonymized data about your usage of the app for research purposes that might be used for publication. If you would like to be informed about the results of this research, please fill in your email in the separate list.

Thank you very much for your participation.

Best regards,
Leonard Wein

Questionnaire – Part 1

This part is about your experiences with museums and mobile technologies.

Please tick the respective field to indicate your answer.

	Never	Occasionally	Often
1. I'm generally curious to learn more about artworks that I see.	☐	☐	☐
2. I read descriptive texts in museums.	☐	☐	☐
3. I use audio guides in museums.	☐	☐	☐
4. I have used QR codes before.	☐	☐	☐
5. I have taken photos with my smart phone in a museum before.	☐	☐	☐

6. I can imagine mobile apps to be useful in museums.	☐ No	☐ Yes
7. I have used mobile apps in museums before.	☐ No	☐ Yes (please specify below in which museums)

_____

End of Part 1 → Please start the museum visit!

Questionnaire – Part 2

This part is about your experience with each method during the experiment.

Please **cross** the respective number to indicate your answer (1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly Agree).

Method 1: Visual Recognition	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
8. Visual Recognition is suitable to access information in museums.	1	2	3	4	5
9. I enjoyed using Visual Recognition.	1	2	3	4	5
10. Visual Recognition was too slow.	1	2	3	4	5
11. Visual Recognition was accurate.	1	2	3	4	5
12. Visual Recognition was difficult to use.	1	2	3	4	5

Method 2: QR Codes	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
13. QR Codes are suitable to access information in museums.	1	2	3	4	5
14. I enjoyed using the QR Codes.	1	2	3	4	5
15. QR Codes were too slow.	1	2	3	4	5
16. QR Codes were accurate.	1	2	3	4	5
17. QR Codes were difficult to use.	1	2	3	4	5

Method 3: Number Codes	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
18. Number Codes are suitable to access information in museums.	1	2	3	4	5
19. I enjoyed using the Number Codes.	1	2	3	4	5
20. Number Codes were too slow.	1	2	3	4	5
21. Number Codes were accurate.	1	2	3	4	5
22. Number Codes were difficult to use.	1	2	3	4	5

This part is about your overall experience during the experiment.

23. Which method do you prefer? ☐ Visual Recognition ☐ QR Codes ☐ Number Codes ☐ Undecided

24. What are the reasons for your preference?

_____

_____

_____

25. Did you encounter any difficulties using the app? ☐ No ☐ Yes (please specify below)

_____

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
26. The presented background information was according to my expectations.	1	2	3	4	5
27. Using the app affected my experience during the visit positively.	1	2	3	4	5
28. Using the app was better than reading wall texts.	1	2	3	4	5
29. I could imagine using an app featuring my preferred method for regular visits.	1	2	3	4	5

30. What other features would you like to see in a mobile guide?

_____

31. Is there anything that should be changed about the Visual Recognition-method?

_____

Demographic Information

32. Age ☐ under 30 ☐ 30-50 ☐ over 50

33. Gender ☐ Female ☐ Male

34. How knowledgeable are you about arts?
☐ I don't know much.
☐ I know the major trends.
☐ I know many artists and their work.

End of Questionnaire

Thank you very much for participating and don't forget the email list if you would like to be informed about the results.

APPENDIX B – UI DEVELOPMENT

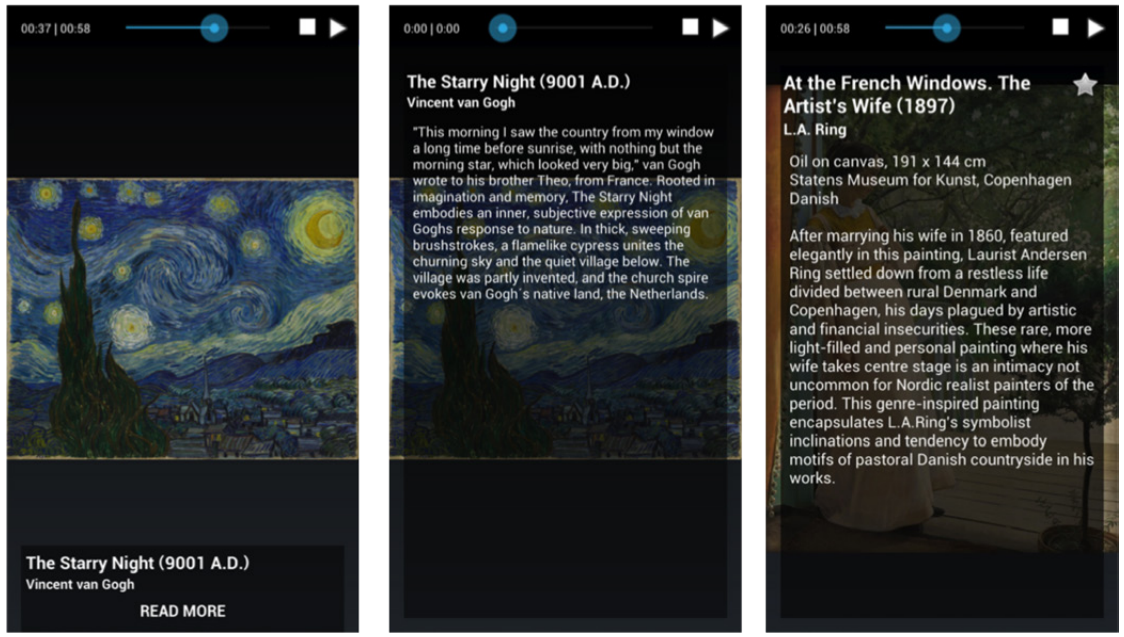


Figure 19: *Information-Views. Two-step Information-View from the Huis Marseille (left & center), Unified Information-View from the Groninger Museum (right)*

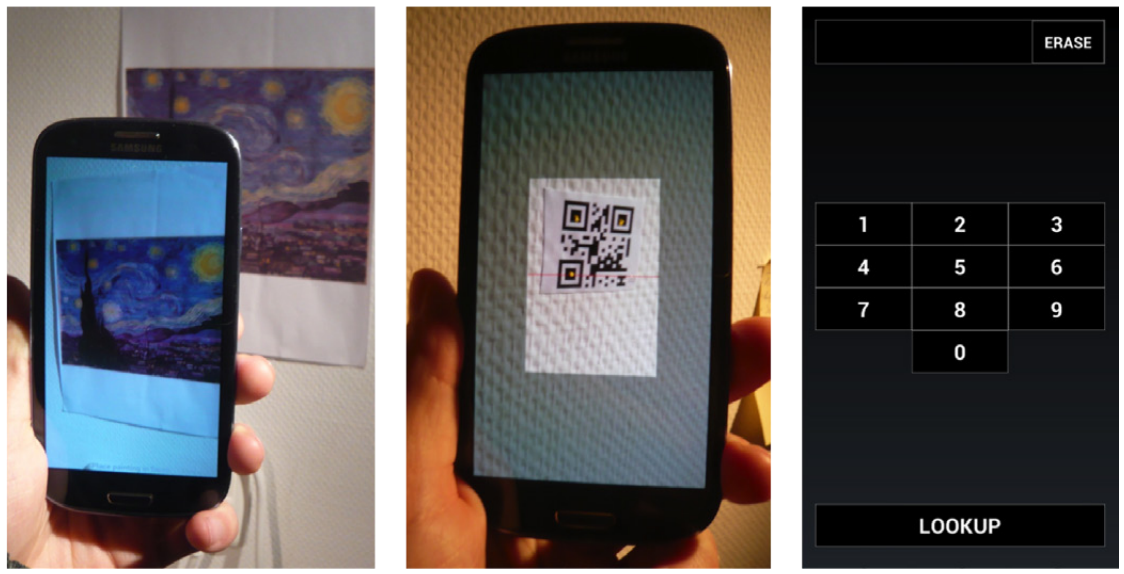


Figure 20: *Method-View. Left VR, note small instructions text on the bottom; center QR codes, the code has to be placed within the brighter rectangle in the center, yellow dots indicate recognition of a QR code; right Keypad*

APPENDIX C – CONTENT FOR THE TWO MUSEUM GUIDES

Content Creation and Sample Commentaries:
The content for the database for the two museums was researched using several sources provided by the museums (catalogues, leaflets, wall texts and websites) as well as independent web research (artist's websites, gallery websites, Wikipedia and art blogs). In total, content was created for 62 artworks. Furthermore, content was only available in English (translations were not possible due to time constraints). Commentaries at the Groninger Museum were made consistently shorter and more focused on each painting (as far as possible with available information) after initial feedback from the Huis Marseille. Below are two sample texts for each museum used in the experiments.

Artwork	Commentary
Luc Delahaye - Death of a Mercenary (May 2011)	'Series: Various works: 2008-2011
Huis Marseille	**About the Photo** A mercenary with the loyalist forces of Colonel Gaddafi during the takeover of the town of Tawergha, Libya, by rebel fighters. Digital C-print, 225 cm x 173 cm
	Artist's Statement I try to put myself in situations that I feel have a certain relevance regarding what we call a shared destiny. The reality I'm interested in is that of people who struggle to act upon it as much as they are subject to it. I sometimes work where power presents itself as a spectacle, as an event produced for or with the media, and my pictures may then take an ironic undertone. But I photograph the ordinary man more often than the leader. I usually stay at the distance where the human relationships are visible, multiple, active and where they remain problematic. I'm interested in narration and in photography's phenomenological hold on the real. There's often a certain degree of lyricism in my images. It remains fairly cool and contained, but it colors them and seems to arrive as soon as they represent people, especially when they're involved in an action with a tragic dimension. It's a quality that has disappeared from advanced societies, where we are limited to the individual, utilitarian and ultimately absurd gesture. This gives me another reason, probably, to go to those places of hardship. It's clear that I don't really photograph the world as it is, but either as it should not be – hardship – or as it should be – man restored to history, an uncertain destiny yet a possibility of fellowship. **Biographic Information** Luc Delahaye is known for his large-scale colour works depicting conflicts, world events or social issues. His pictures are characterised by detachment, directness and rich details, a documentary approach which is countered by dramatic intensity and a narrative structure. Delahaye started his career as a photojournalist. He joined the photo agency Sipa Press in 1985 and dedicated himself to war reporting. From 1994 to 2004, he was a member of Magnum Photos. His war photography was characterised by its raw, direct recording of news and often combined a perilous closeness to events with an intellectual detachment in questioning his own presence. In 2001, Delahaye ceased collaboration with the press and conducted a radical formal change. His books include Luc Delahaye 2006 – 2010 (2011), History (2003), Une Ville (2003), Winterreise (2000), L'Autre (1999), Memo (1996) and Portraits/1 (1996).

Artwork	Commentary
Edward Munch (Norway) – Portrait of Professor Daniel Jacobson (1908)	Oil on canvas, 128,3 x 73.7 cm Statens Museum for Kunst, Copenhagen
Groninger Museum	Edvard Munch (1863 - 1944) is regarded as a pioneer in the Expressionist movement in modern painting. He suffered as a child with illness, loss, and psychological terror, emotions that characterize many early paintings. Between 1808 and 1809 Munch went in stationary therapy with the renowned Danish therapist Daniel Jacobson, who diagnosed strong manic-depression related to alcoholism. This Portrait of Professor Daniel Jacobson is one of three portraits Edward Munch painted during his therapy. The therapy led to a change of subjects. Munch stopped painting dying persons and corpses and instead focused on peaceful scenes involving landscapes, peasants and fishermen.

Table 6: *Two sample commentaries from the experiment. HTML-tags for formatting have been substituted by visual formatting in Word for better readability.*

AUDIO COMMENTARY:
In total, 42 audio commentaries were created for the two experiments (30 – 120 seconds each). For the Huis Marseille, only the Artist's Statements were recorded; for the Groninger Museum text and audio commentary was identical. A sample audio commentary on Edward Munch's Portrait of Professor Daniel Jacobson (Groninger Museum) can be listened to on SoundCloud: https://soundcloud.com/juicyamsterdam/audio-commentary-edward-munch

DATABASE FILE:
The database (SQLite) was created from a simple SQL file with the following columns: ID, Title, Painter, Description, Time, Audio-File, Image-File. Below is a screenshot of a small database file.

Figure 21: *Screenshot of the SQL-file used to create the database*

APPENDIX D – PHOTO DOCUMENTATION FROM THE EXPERIMENTS

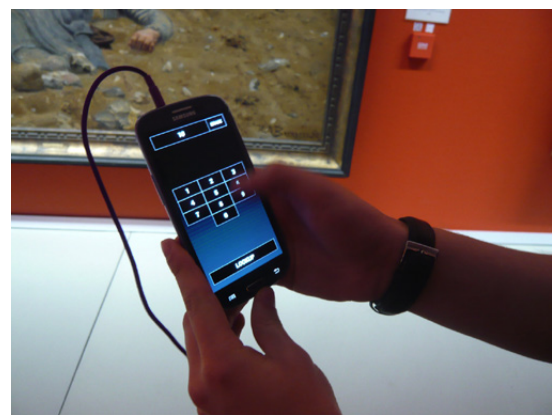
Participant at the Huis Marseille listening to the audio guide.

Participant using VR at the Groninger Museum.

Participant scanning a QR code (Groninger Museum)

Participant using VR from a distance.

Participant scanning a QR code (Groninger Museum)



Participant keying in a number code.

Older visitor taking a photo with a smartphone at the Groninger Museum.

Older visitor taking a photo with a camera at the Groninger Museum.

APPENDIX E – GLOSSARY

Term	Description
3G	3G, short for third Generation, is the third generation of mobile telecommunications technology
Algorithm	A process or set of rules to be followed in calculations or other problem-solving operations, esp. by a computer.
AMUS	Access Method Usability Scale. Usability scale developed in this research by adaptind existing usability scales (such as SUS and UMUX)
Android	Android is a Linux-based operating system designed primarily for touchscreen mobile devices such as smartphones and tablet computers. Initially developed by Android, Inc., which Google backed financially and later bought in 2005, Android was unveiled in 2007
Augmented reality	Augmented reality (AR) is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data.
BRISK	BRISK: Binary Robust Invariant Scalable Keypoints (Stefan Leutenegger, Margarita Chli and Roland Siegwart, 2011)
Critical success factors	Critical success factor (CSF) is the term for an element that is necessary for an organization or project to achieve its mission.
FREAK	Fast Retina Keypoint (Alahi, R. Ortiz, and P. Vandergheynst, 2012)
GPS	Global Positioning System
ID	short for 'identifier'
iOS	OS (previously iPhone OS) is a mobile operating system developed and distributed by Apple Inc.
iPhone	the iPhone is a line of smartphones designed and marketed by Apple Inc. It runs Apple's iOS mobile operating system. The first generatino was introduced in 2007.
Keypad	Access method, used interchangeably with number codes in this research
MGS	Multimedia Guide Scale (Othman, Petrie and Power, 2011)
Mobile Application (app)	A mobile application (or mobile app) is a software application designed to run on smartphones, tablet computers and other mobile devices.
NFC tags	Near Field Communication tags, similar to RFID

Number codes	Also referred to as Keypad method. Frequently used in conventional audio guides. One of the three access methods employed in this research.
ORB	Oriented Brief (Rublee et al., 2012)
primary key	Unique ID in a relational database
QR codes	Short for Quick Response Code, type of two-dimensional, machine-readable matrix barcode. One of the three access methods employed in this research.
Recommender System	Recommender systems or recommendation systems are a subclass of information filtering system that seek to predict the 'rating' or 'preference' that user would give to an item (such as music, books, or movies) or social element (e.g. people or groups) they had not yet considered, using a model built from the characteristics of an item (content-based approaches) or the user's social environment.
RFID	Radio Frequency Identifier. Transmits information on short distance via radio waves.
SIFT	Scale-invariant feature transform (or SIFT) is an algorithm in computer vision to detect and describe local features in images. The algorithm was published by David Lowe in 1999.
Smartphone	A smartphone is a mobile phone built on a mobile operating system, with more advanced computing capability and connectivity than a feature phone.
SQL	Structured Query Language (SQL). A data definition and management language for relational databases. SQL front ends most relational DBMS.
SQLite	SQLite is a relational database management system contained in a small (~350 KB) C programming library. In contrast to other database management systems, SQLite is not a separate process that is accessed from the client application, but an integral part of it.
SURF	SURF (Speeded Up Robust Features) is a robust local feature detector, first presented by Herbert Bay et al. in 2006, that can be used in computer vision tasks like object recognition or 3D reconstruction. It is partly inspired by the SIFT descriptor.
SUS	System Usability Scale (Brooke, 1986)
UI	User interface
UMUX	Usability Metric for User Experience (Finstad, 2010)
Usability	The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.
User Experience (UX)	User experience (UX or UE) involves a person's emotions about using a particular product, system or service. User experience highlights the experiential, affective, meaningful and valuable aspects of human-computer interaction and product ownership. Additionally, it includes a personÕs perceptions of the practical aspects such as utility, ease of use and efficiency of the system. User experience is subjective in nature because it is about individual perception and thought with respect to the system. User experience is dynamic as it is constantly modified over time due to changing circumstances and new innovations.
varchar	A varchar or Variable Character Field is a set of character data of indeterminate length
Virtual Reality	Virtual reality (VR - not used in this research to avoid confusion with visual recognition) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones.
Visual recognition	The addition of some form of computer intelligence and decision making to digitized visual information, received from a machine sensor such as a camera.
VR	acronym referring to Visual Recognition
WIFI	Wi-Fi (also spelled Wifi or WiFi) is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high-speed Internet connections.

Table 7: *Photo Documentation from Experiment*

Silence and Subjectivity in Henry James's *The Portrait of a Lady* and *The Wings of the Dove*

Ianthe Schepel

ABSTRACT

Questions of subjectivity and the ambiguities that attend it have been the mainstay of scholarship on Henry James's *The Portrait of a Lady* and *The Wings of the Dove*. On a conceptual level, subjectivity has been evaluated within discussions of consciousness; on the level of narrative, the focus has lain on the associations between interiority and interior architectural spaces, and on the relation between subjectivity and ambiguity in acts of speech. Both conceptually and narratively, critics have often not fully embedded subjective experiences within the growth of characters and narrative progression. This thesis takes a new approach by introducing silence as a narrative technique that assumes the form of a space that is lived through, enclosing and revealing subjective experiences. Silence opens up the story transpiring between the lines, the crucial spells of realisation and communication that impact on the development of characters and the larger narrative, by virtue of encompassing a density of meaning that acts of speech cannot contain. This thesis specifically examines subjectivity during solitary moments of silence and during acts of nonverbal communication that variably mobilise and disrupt "conspiracies of silence". Because silence has spatial as well as temporal dimensions, it forms a new conceptual framework with which to consider the construction of subjectivity: silence unfolds how subjective experiences and the changes these bring about are reflected formally in the text. This thesis paves the way for future studies to consider the roles of silence in conceiving subjectivity across different literary periods and genres.

INTRODUCTION

Silence saturates Henry James's *The Portrait of a Lady* and *The Wings of the Dove*. In these novels, silence mediates between subjective experience and the outside world: it registers moments of reflection and revelation as well as artful behaviour and coercion. Accordingly, silence provides a promising framework with which to address questions of subjectivity and the ambiguities that attend it – these questions have formed the cornerstones of scholarship on James, but their intricate relationship with silence has been left untouched.

Conceptual discussions of subjectivity emanate from the contested notions of consciousness and selfhood in James, where consciousness is understood as the awareness of knowledge that a person possesses at a certain point in time.[1]

While the two most influential scholars in this field, Leo Bersani and Sharon Cameron, both contend that representations of consciousness in James stand apart from subjectivity, their notion of consciousness differs.[2] Bersani's poststructuralist conviction that consciousness is a wholly linguistic performance, disconnected from characters' psychology, is revised by Cameron, who argues that consciousness is indeed external, but defines rather than responds to its external situations.[3] The philosopher Robert Pippin, in contrast, believes that consciousness in James is intersubjective, that "it is consciousness of somebody's consciousness of you".[4] This idea of consciousness is expanded by Omri Moses, who, focusing on action rather than epistemology, claims that characters' internal motivations originate in mandatory interaction with the social environments through which they

move.[5] As characters' relationships with their social environments are complex, he argues, crucial narrative moments elicit the suspension of action rather than action itself; in other words, characters first need to assimilate whatever they have just experienced before they can arrive at any form of motivation.[6] This thesis will conjoin Pippin's and Moses's conceptual framework by focusing on the relation between knowledge, action, and (inter)subjectivity. Pippin already signals the connections with silence when explaining how one character can arrive at awareness through another, analysing a "'silent explosion' of revelation" in James's *The Golden Bowl*.[7] This thesis will expand on the importance of silence in such moments of (inter) subjectivity.

Critical approaches to understanding how subjectivity takes shape on the level of narrative in James's work have often relied on architectural models or conceived of its ambiguities as interpretive spaces. For example, critics such as Collins, Fischer, Sabiston, and Tintner have argued that the border between subjective experiences and the places in which these transpire is blurred in *The Portrait of a Lady*: houses figure as personifications of their inhabitants, while, reciprocally, characters' interiority is described in architectural imagery.[8, 9] Marshall extends this argument by suggesting that the interior of houses becomes the stage for intrigues, the place where drama is most fully realised, thereby shaping representations of intersubjectivity.[10, 11, 12] Speaking about James's composition of interiority more generally, Blackwood points out that James's use of architectural imagery encourages the reader to think of his characters' minds as "deep, vast space".[13] The connections thus made between subjectivity and architectural place seem to reflect the reification of human relationships, a theme Foeller-Pituch and Boyle Machlan believe central to many of James's works, and late-Victorian fiction more generally.[14] Curiously, silence has not been considered in the context of this connection between subjectivity and place. Silence not only accompanies moments of intrigue, but also has a sense of mass; it is something that is built up. James's private correspondence substantiates the latter notion of silence: he began many of his letters by apologising for his prolonged silence toward the addressee, to which he often added a spatial description, e.g. when of he speaks of his "great desire to punch a hole in the massive silence which has grown up between us" or laments that his "silence has become so dense and coagulated".[15]

Silence is, moreover, an open interpretive space well-suited for examining the relation between subjectivity and ambiguity, but critical work on *The Wings of the Dove* has tended to address this relation by studying James's "notoriously difficult, sometimes even undecidably obscure" language.[16] Many readers have struggled with the novel's indeterminacy, which issues from a wide range of formal techniques that seem to create an interpretive void: for example, Ballam argues that James's use of modal verbs proliferates the number of meanings a statement can take on, making it difficult to grasp, while King notes that the reader is excluded from the novel's decisive moments, leaving gaps in the narrative that s/he must then fill.[17] White is one of many who argue that the novel's literary value lies precisely in its urging the reader to read attentively and engage with the text actively.[18] For all these explorations of absences, many critics refer to *The Wings of the Dove* as a text of density and entanglement. Kuchar argues that the "accumulation of consciousnesses" and constant shifts between these points of view account for the novel's simultaneous impenetrability and fluidity.[19] Morse, an early critic of *The Portrait of a Lady*, observed that James makes it difficult to differentiate between characters when they speak.[20] Such remarks abound in criticism on *The Wings of the Dove* – Yeazell even maintains that in conversation, characters' subjectivities seem to merge to a single self.[21] Silence mirrors the complexity of the novel in being at once dense and vacuous, heavy with meaning and open to many readings.

The dominance of these spatial terms in criticism seems to derive, in part, from the spatial language James uses in his theories about narrative technique that were delivered in his prefaces to the New York Edition of his novels – prefaces that are postulated to have formed the basis of modern day Anglo-American narrative theory.[22] In his preface to *The Portrait of a Lady*, James seems to prefigure later connections between interior architectural spaces and subjectivity by speaking of the "house of fiction".[23] The novel as a genre forms a house facing the spectacle of human life, and behind each one of its "million" windows stands an author who observes and takes record of his own distinct impression of the scene.[24] Echoing his arguments in *The Art of Fiction*, James states that the sole qualification against which to measure a novel is whether its subject is "the result of some direct impression or perception of life". [25],[26] He introduces his protagonist Isabel as a "rare object", whose consciousness he placed in one "scale", balancing it against the consciousnesses of secondary characters in the other scale. [27] With suchlike "technical rigour" he managed to build "the neat and careful and proportioned pile of bricks that arches over" these characters.[28] Indeed, he calls *The Portrait of a Lady* a "literary monument".[29] Kelly makes the acute observation that James is striving to prove *The Portrait of a Lady's* "architectural competence" in this preface, which may have caused the prevailing focus among critics on James's treatment of architecture within the novel itself.[30]

In his preface to *The Wings of the Dove*, James's use of two metaphors for the formal representation of subjectivity, medal and architectural block, emphasises that there needs to be balance between spatial and temporal dimensions in this representation. James explains how he designed the succession of "points of view", "fixing them…exactly" so that they would be

[1] Labrie, "Idea of Consciousness", 524.
[2] Ibid., 139.
[3] Ibid., 135.
[4] Ibid., 117.
[5] Ibid., 116, 117, 125, 134.
[6] Pippin, Modern Moral Life, 75.
[8] Collins, "Point of View"; Fischer, "A Phenomenological Reading"; Sabiston, "The Architecture of Consciousness"; Tintner, "Iconography".
[9] In "Reading the House", Mezei and Briganti note that the comparison between literature and architecture goes back to ancient times: "novels and houses furnish a dwelling place – a spatial construct – that invites the exploration and expression of private and intimate relations and thoughts" (839).
[10] Marshall, "Performances", 266.
[11] In "Architecture and Genre", Boyle Machlan deviates from the personification-reading to argue that each house in the novel represents an amalgam of literary genres, with which James would draw attention to the restricted agency of his characters and, by extension, his own artistic expression. This reading seems to resonate with Marshall's notion of the house as a centre for dramatic performances.
[12] In "Price of 'Mere Spectatorship'", Despotopoulou makes a similar point as Marshall by speaking about "the intense public stage of interiors" in *The Wings of the Dove* (231).
[13] Blackwood, "Psychology", 275.
[14] Foeller-Pituch, "Rome as Global City", 294; Boyle Machlan, "Architecture and Genre", 399.
[15] James, The Letters of Henry James, Volume I, 30; James, The Letters of Henry James, Volume II, 146.
[16] Stowe, "James's Elusive Wings", 188.
[17] Ballam, "Modalities of Perception"; King, "James's Opaque Style", 4.
[18] White, The Uses of Obscurity, 147.
[19] Kuchar, "Consciousness and Variation of Style", 174.
[20] Richmond, "Early Critical Reception", 160.
[21] Yeazell, "Talking in James", 68.
[22] Hale, "Invention of Novel Theory", 79; Watson, "Lost Prophet of Realism", 485.
[23] James, Author's Preface to *The Portrait of a Lady*, 7.
[24] Ibid.
[25] Ibid., 6; Cf. James, "The Art of Fiction", 188, 197, 201.
[26] In "Limitations of Realism," Emerson provides a lucid overview of how James's concept of realism shifted over the course of his career, noting in particular how James increasingly stressed the importance of an author's "imagination".

"solid blocks of wrought material…as to have weight and mass and carrying power".[31] He is pleased with how he has fixed these points of view, as he believed that any formal break with the subject of perception does "rather scatter and weaken" fiction.[32] However, when looking at the temporal dimensions of these points of view, he can only "mark the gaps and the lapses…the absent values, the palpable voids, the missing links, the mocking shadows" – he thus believed his depiction of characters to be incomplete.[33] Furthermore, James finds that his neglect of Milly's point of view in the second half of the novel caused a crucial imbalance that forced him to "produce the illusion of mass without the illusion of extent". [34] The novel's two plots, Milly's "stricken state" and "the state of others as affected by her", were to form the two sides of a medal: "could I but make my medal hang free, its obverse and its reverse, its face and its back, would beautifully become optional for the spectator" – equal light should therefore have been shed on each plot, were it not that the novel "[rests] on a misplaced pivot".[35] Subjectivity thus undergoes changes in the course of the narrative, and it ought to be depicted with sufficient detail to achieve "mass".

This thesis explores silence as a narrative technique with both spatial and temporal dimensions, allowing a study of subjectivity that is alert to character development and narrative progression. It argues that silence can be understood as a space that is "lived", the subjective experience of which is contingent on its timespan and place and on the power relations it encloses. [36, 37] Chapter I, "The Silence of Lonely Places", will examine solitary moments of silence that enable reflection and revelation, paying special attention to the relations between the physical places where these occur and the subjective experience of time within, and the places where these occur in the novel's structure and the narrative arc. Chapter II, "Conspiracies of Silence'", investigates the communicative functions of silence, particularly the power relations entailed in the association between artful behaviour and nonverbal communication. An early anonymous reviewer of *The Wings of the Dove* claimed that James wrote the novel for readers "who have learnt to read constantly between the lines".[38] Reading "between the lines" includes probing the ambiguities inherent in omissions and silences, and this thesis will foster understanding of how these "spaces" can carry narrative for the characters as well as the reader. Together, its chapters will establish the relations between silence and subjectivity within the story and the form of James's novels.

[27] James, Author's Preface to *The Portrait of a Lady*, 8, 11.

[28] Ibid., 11.

[29] Ibid.

[30] Kelly, Introduction to *The Portrait of a Lady*, v.

[31] James, Author's Preface to *The Wings of the Dove*, 9.

[32] Ibid., 12.

[33] Ibid., 9.

[34] Ibid., 14.

[35] Ibid., 7, 16.

[36] In Geographies of Writing, Reynolds differentiates between spaces and places: the former is uninhabitable but crucial in structuring habitats and practices, while the latter is fixed and determined by people and events (181). Space is thus "the more conceptual notion – a realm of practices" (ibid).

[37] My concept of silence is inspired by Edward Soja's notion of "Thirdspace". See Borch, "Interview with Edward W. Soja".

[38] "Mr. Henry James's New Book", 481.

CHAPTER I "THE SILENCE OF LONELY PLACES"

Silence is indispensable to moments of reflection and revelation in James; in turn, the physical places in which these moments transpire evoke a sense of time that impacts on the subjective experience of those moments, while their narrative place strongly affects the narrative arc. In *The Portrait of a Lady,* there are at least four of these silent moments. While critics such as Fischer and Sabiston have aligned private places with interiority in the novel, they have mostly abstained from considering public places. The moments of solitary silence that occur in private places in *The Portrait of a Lady* circumscribe physical stasis and intense mental activity accompanied by a sense of timelessness; these moments cause a strain within the larger narrative. In contrast, silent moments that occur in public places mediate a sense of history that invites imaginative connections with the past and with unknown others; these form moments of relief.

The deepest strain in the narrative arc is indeed caused by an instance in the drawing room. As the drawing room is the novel's setting for intrigue, the reflections and revelations that materialise here have a deeply personal impact. In this episode, Isabel features as the silent witness of a habitual scene in which she nevertheless senses "something new" (PL, 349). Silence is both the requirement of her sensing it and an essential element of the sense: "the soundlessness of her step" prevents Isabel from breaking the "familiar silence" that hangs between Osmond and Madam Merle (ibid). Although the moment's transitoriness is emphasised –"for a minute they were unaware she had come in" – time seems to come a standstill: the scene has an arresting power over Isabel, who stops to examine which of its fragments cause it to leave an anomalous "impression"; during Isabel's analysis, the whole scene, too, "arrived at a…pause" (ibid). This tension between fleetingness and stasis is perpetuated when the connection is made between the moment's transitory and revelatory nature: "the thing made an image, lasting only a moment, like a sudden flicker of light" (ibid). Because, when situated within the larger narrative, the impression endures, radically changing as it does Isabel's idea of Osmond and Madam Merle's relationship. Leo Bersani has recognised that James's fiction is loaded with such "visual shocks", where "betrayal takes the form of an intimacy which excludes its witness".[39] The mundane secret between Osmond and Madam Merle that Isabel begins to uncover was supposed to remain within four walls and it does so, in effect, but from this point on between the four walls of Isabel's mind. This silent moment within the private sphere exerts pressure on the narrative arc, because it continues to cause Isabel distress: not only does the scene haunt her perpetually, but the scene is reticent in itself – although its significance is evident to Isabel, many chapters will pass before she fully understands its meaning.

Isabel's remembrance of that moment is most significant at the end of chapter 42 – a chapter in itself revelatory, comprising Isabel's nightly meditation on her destructive marriage. Nowhere else in the novel does James offer such a prolonged and profound exposition of Isabel's interiority.[40] The lengthy meditation is triggered by Osmond's call on Isabel to take responsibility for securing marriage between Pansy and Lord Warburton: "There was something in [his words] that suddenly made vibrations deep, so that she had been afraid to trust herself to speak" (PL, 361).[41,42] Osmond has Isabel under his thumb, but his demand repels her to such a degree that she fears she will not be able to restrain herself from rearing up against him and will subsequently have to suffer for it. Alone in a "soundless saloon" by the fireplace, and

[39] Lamm, "A Future for Isabel Archer", 254

[40] The chapter seems to foreshadow the streams of consciousness that would come to permeate James Joyce's and Virginia Woolf's fiction.

[41] In "Eliot Rewritten, James Revisited", Berkman argues that James is rewriting a scene from George Eliot's *Middlemarch* here: "both authors have their heroines endure an excruciating all-night vigil after their husbands place egregious and demeaning demands". Berkman believes that *The Portrait of a Lady* forms James's attempt at writing an improved version of Eliot's novel.

[42] Isabel's sentiment seems to echo the "doctrine of vibrations" that Enlightenment philosopher David Hartley's presents in his *Observations on Man*, where pain is postulated to result from deep vibrations in the nerves.

"for a long time, far into the night and still further", Isabel turns her subjective gaze inward to achieve full consciousness of her relation to Osmond (PL, 371; 361). James himself called it "obviously the best thing in the book" and "a representation simply of [Isabel] motionlessly seeing".[43] Once again, a sense of timelessness is evoked through Isabel's deep concentration on the analysis of images: "She heard the small hours strike, and then the great ones, but her vigil took no heed of time. Her mind, assailed by visions, was in a state of extraordinary activity" (PL, 371). Through her intense mental activity in this scene she comes to realise that "She had lived with [Osmond's mind], she had lived in it almost – it appeared to have become her habitation" (PL, 365). The "vibrations" that Osmond's request causes in her may well be stuck alternating between the following two poles: he demands she take responsibility for a task, but he simultaneously refuses her any sense of autonomy. Although she believes her agency to be at "a dark, narrow alley with a dead wall at the end", she continues to struggle with Osmond's command that she marry off Pansy (PL, 363). When she finally breaks free from her thoughts, she is overcome by "a remembered vision – that of her husband and Madame Merle unconsciously and familiarly associated" (PL, 372). Almost like a spot of time in Wordsworth's Prelude, the moment's impression has gained in force through memory.[44] The recurrence of that image of a conspiratorial silence causes a sudden breakthrough: Isabel will refuse to silently comply with Osmond's command, thereby restoring some sense of agency. Within the larger narrative, the meditation has served to build up Isabel's feeling of claustrophobia to accentuate this breakthrough.

Moments of reflection and revelation take shape in a decidedly different way in the public places of Rome: the focus there lies on Isabel's gaze outward, on her finding solace through imaginatively connecting with the past, allowing the narrative to briefly enter calmer waters. The first instance occurs just after Lord Warburton has left Isabel alone in the Capitol gallery, and she is about to be interrupted by Osmond entering the room; within the larger narrative arc, the moment is situated between the closure of Warburton's pursuit of Isabel and the beginning of Osmond procuring her.[45] Isabel sits down to listen to the "eternal silence" of ancient Greek statues, "which, as with a high door closed for the ceremony, slowly drops on the spirit the large white mantle of peace" (PL, 262). To Isabel,

the Roman air is an exquisite medium for such impressions. The golden sunshine mingles with them, the deep stillness of the past, so vivid yet, though it is nothing but a void full of names, seems to throw a solemn spell upon them (ibid).

The moment may be "closed" off and wrap Isabel's spirit in a "mantle of peace", but it retains a sense of space as the "Roman air" is shown to mediate "sunshine" and "deep stillness". Isabel fantasises about the statues coming to life, "wondering to what, of their experience, their absent eyes were open, and how, to our ears, their alien lips would sound" (PL, 263). Her dream of interaction implies a symbiosis of past and present. The pull of the present, of narrative progression, manifests itself in the passage's conclusion: "At last, however, her attention lapsed, drawn off by a deeper tide of life" (ibid). She is drawn back from the past to the present, and accordingly, the statues come to represent characters in her life. As Tintner notes, upon Osmond's entrance Isabel associates the Dying Gladiator with the emotionally wounded Lord Warburton, and Antonius and the Faun ("the ripest, perhaps the too ripe, development of canons of beauty, canons to which Osmond has devoted his life") with Osmond.[46] Through connecting with the past in solitariness and silence, Isabel managed to cut off her imagination from her present situation, preventing her, there and then, from arriving at those associations. Hence, Isabel herself as well as the larger narrative experiences a momentary relief.

The sense of historical continuity that the public places of Rome evoke is crucial once again toward the end of the novel: Isabel manages to move beyond her feelings of anguish about her marriage by positioning them within larger historical problems. This moment resonates with a short passage that was related earlier in the novel, set in the Forum Romanum: "From the Roman past to Isabel Archer's future was a long stride, but her imagination had taken it in a single flight" (PL, 251). Isabel's life is in ruins, but from the ruins of Rome that "yet still were upright" she gains a certain hope (PL, 439). "The silence of lonely places" that she visits on her afternoon drive turns her "modern" subjective sufferings "objective", making them "small" (ibid). It is remarkable that Isabel feels "companionship", intimacy and spirituality in "starved" places, in absence and voids, given that her marriage is also a "lonely place" (ibid). Yet the silence of her marriage is one of suffocation and tight regulation by Osmond; the silence Isabel finds in the ruins and churches of Rome is liberating because she finds "suggestiveness" in the objects, it triggers her imagination and gives her a "haunting sense of the continuity of the human lot", much like the statues in the Capitol gallery (ibid). Crucially, this scene follows immediately after Isabel understands what she saw in the drawing room between Osmond and Madam Merle: "It had come over here like a high-surging wave that…Madam Merle had married her" (ibid). By "[taking] old Rome into her confidence", Isabel reconciles herself with the turn her life has taken in marrying Osmond: "before Isabel returned from her silent drive she had broken its silence by the soft exclamation: 'Poor, poor Madame Merle!'" (ibid). Another moment of solitary silence in the cityscape of Rome therefore successfully reduces Isabel's and the narrative's tension.

Like *The Portrait of a Lady*, *The Wings of the Dove* contains at least four important moments of solitary silence. While in former novel the temporal experience of such moments and their effect on the narrative arc are bound up with the dichotomy between private and public places, the latter novel evokes a strong sense of historical continuity in each place where such silent moments occur; the weight of history seems to contribute to the narrative impulse these moments generate. Indeed, strung together, these moments signal the crucial changes in Milly's disposition toward life throughout the novel – changes that she acts upon.[47]

The first of these moments is effectively the germ of the entire narrative. Importantly, the moment is narrated by Mrs Stringham, which begs the question whether it is even revelatory for Milly, or whether Mrs Stringham merely reads certain meanings into it. Mrs Stringham searches for Milly in the Alpine meadows and finds her "seated at her ease…[on] a slab of rock at the end of a short promontory or excrescence that merely pointed off to the right into gulfs of air" (WD, 89). Sound becomes a matter of life and death in the passage, as Mrs Stringham fears that the slightest sound would cause Milly to fall off her perch. Through Mrs Stringham, the reader is led to believe that Milly is experiencing some kind of epiphany, as she sits "in a state of uplifted and unlimited possession…looking down on the kingdoms of the earth", thus appearing to take in all the possible meanings of life (ibid). Millicent Bell has identified the passage as an analogy of Christ's renunciation of the third temptation, through which he insisted on his humanity.[48] This reading seems entirely justified: the literal and figurative heights at which Milly finds herself in this passage resonate with her image of being a "dove", a religious symbol, while the aftermath of the moment forms Milly's acceptance of "taking full in the face the whole assault of life" (WD, 90). Yet the setting adds more layers of history: the Alps are associated with the Grand Tour of the seventeenth and eighteenth century, a ritual for upper class men through which they acquainted themselves with the history of Western civilization. What is more, the image conjured here bears a striking resemblance to Caspar David Friedrich's painting *Wanderer above the Sea of Fog* (1818), which John Lewis Gaddis interprets as "suggesting at once mastery over a landscape and the insignificance of the individual within it. We see no face, so it's impossible to know whether the prospect facing the young man is exhilarating, or terrifying, or both".[49] Likewise, neither Mrs Stringham nor the reader will come to know how Milly experiences the prospect she is facing – only its effect will be exposed. There is a tension between this "'view' pure and simple" and the

[43] James, Author's Preface to *The Portrait of a Lady,* 15.

[44] Cf. Wordsworth, *The Prelude,* Book Twelve, lines 208-25.

[45] In "Eliot Rewritten, James Revisited", Berkman argues that James is once again rewriting an important moment in Eliot's *Middlemarch* in this scene.

[46] Tintner, "Iconography", 148.

[47] In "Consciousness and Variation of Style", Kuchar argues that Milly's deepening self-consciousness effects increasing levels of intimacy between her and the reader, which are conveyed by the distinct narrative style James employs when relating the story from her point of view (171).

[48] Bell, "Being Possessed and Possessing", 103.

cultural associations it evokes (WD, 89). It is intriguing that this contrast is visible only to Mrs Stringham, not to Milly herself, considering that Milly subsequently articulates a sudden wish to "take the road again", toward the drawing rooms of London, where she will embrace the culture and history in which the Alpine passage is steeped (WD, 91).

The historical connections feature much more explicitly, also for Milly, in the silent moment of reflection and revelation at Lord Mark's estate, where they prove crucial to the moment's effect. The man of the house leads Milly to the image of the Bronzino, an Italian painting, the figure of which she is supposed to greatly resemble.[50] When laying eyes on the picture,

Once more things melted together – the beauty and the history and the facility and the splendid midsummer glow: it was a sort of magnificent maximum, the pink dawn of an apotheosis, coming so curiously soon. What in fact befell was that, as she afterwards made out, it was Lord Mark who said nothing in particular – it was she herself who said all (WD, 143).

The "magnificent maximum" may be triggered by the painting, but the meaning issues from Milly herself; the presence of Lord Mark may facilitate the impression the painting makes, as he has drawn comparisons between Milly and this historical figure, but it is her own recognition that the figure is "dead, dead, dead" and it affects her deeply (ibid).[51] Milly becomes conflated with a figure long past, and she finds herself alone in the revelation – Lord Mark simply "hadn't understood" its significance (ibid). Given that her sense of an ending "[comes] so curiously soon", one may deduct that the Alpine passage gave her a sense of hope that the Bronzino passage smothers. Yet to Milly, "It was perhaps as good a moment as she should have with anyone", because it only further amplifies her motivation to live and experience that the Alpine scene has apparently instilled (ibid). As the remainder of the chapter shows, Milly had already been planning to visit Dr Strett; however, in terms of narrative form it is surely not a coincidence that her visit directly follows this existential moment.

Dr Strett's subsequent encouragement that Milly "live" generates the third and most lengthy silent moment, which occurs in the streets of London (WD, 158). Dr Strett's words work as an "impulse" – the rush with which Milly attempts to achieve a state of life is one that no one else could possibly keep up with (ibid). While she realises that Dr Strett's urging her to live must mean that she is dying, she finds "beauty [in] the idea of a great adventure" (WD, 159). She is adamant that "her only company must be the human race at large, present all around her, but inspiringly impersonal, and that her only field must be…the grey immensity of London" (WD, 158). Milly is romanticising her situation in the literary sense; much like Isabel Archer, Milly can frequently be caught testing her circumstances against the novels she has read. Milly believes herself to be "a soldier on a march", whose journey is minutely followed: "it was quite as if she saw in people's eyes the reflection of her appearance and pace" (WD, 159). As this soldier, she seems to be walking through a Dickens novel, seeing "side-streets peopled with grimy children and costermonger's carts, which she hoped were slums" (ibid). She is self-conscious about her role-playing, wanting the story that she creates around her to be well-proportioned and fitting the narrative arc of its genre:

But for the fear of overdoing this character she would here and there have begun conversation, have asked her way; in spite of the fact that, as that would help the requirements of adventure, her way was exactly what she wanted not to know (ibid).

The weight of literary history, the idea of what an interesting life story should encompass, seems to be pushing her onward, greatly amplifying the impulse that Dr Strett's words initiated. The chapter ends with Milly's statement, "I'm to go in for pleasure", and she is to leave London for Venice, where reality will entirely fail to measure up to the fantasies that she has produced (WD, 165).

In Venice, James plays on the association between architectural space and interiority again by letting Milly pass her days alone on the upper floor of Palazzo Leporelli. "Hung about with pictures and relics, the rich Venetian past…was here the presence revered and served," and Milly likewise tries to retreat from the present (WD, 268). The introduction of the Venetian scene forms a moment of deep reflection for Milly, it being "the first time she had been alone" after many weeks of travelling (WD, 266):

Milly moved slowly to and fro as the priestess of the worship. Certainly it came from the sweet taste of solitude, caught again and cherished for the hour; always a need of her nature, moreover, when things spoke to her with penetration. It was mostly in stillness they spoke to her best; amid voices she lost the sense (WD, 268).

Milly's movement "to and fro" signals that her narrative is coming to a standstill, but at the same time it creates the sense of her preparing to generate life's final impulse. Her religious devotion here is not for the divine, but rather for the ancient palazzo that has become her silent, solitary place of refuge, where she still has a hold on her life and can try to navigate the meaning of her relationships with others. Milly takes this opportunity to look back on her travels from London to Venice and her growing alienation from her friends, Kate in particular: "She saw things in these days that she had never seen before" (WD, 269). She finds relief in thinking of her Venetian servant, Eugenio, the sole person who makes it perfectly clear that he is only interested in her money while simultaneously understanding all her needs – he has inspired her to consider making "complete use of her wealth" (WD, 272). The moment reaches its climax when Milly realises that

She had a vision of clinging to [the palazzo]…She was in it, as in the ark of her deluge, and filled with such a tenderness for it…She would never, never leave it – she would engage to that; would ask nothing more than to sit tight in it and float on and on (WD, 273).

Toward the end of the novel, the character of these solitary moments of silence has changed: no longer do they arouse in Milly a will to live adventurously and connect with other people. Instead, she finds romance in the idea of exclusion from society and an eventful life; this is what she would give all her money for. Her "image of never going down, of remaining aloft in the divine dustless air" echoes the heights at which she sat perched in the Alps, but while she first seemed a dove considering where best to land, she now longs to drift along in the "dustless air" where her pain is minimal (WD, 275). Milly's devotion to a palazzo so saturated with art objects indicates that the end is near, that she will soon turn into a portrait like the Bronzino – an impression that is deepened by the fact that Lord Mark, owner of the Bronzino, breaks this silent moment. Together, the "silences of lonely places", places bearing the weight of history, have marked the moments that spurred Milly on a flight route perhaps best symbolised in the U-shape: she descended from the Alps into the houses and streets of England to experience life, only to flee/fly up again into the high realms of her palazzo, where she could peacefully reconcile herself with her fate.

In *The Wings of the Dove*, James therefore disengages solitary silences from belonging to one part of the dichotomies private/public and interiority/exteriority, to instead establish solitary silences as moments that enclose dichotomies within them – perhaps most crucially those of past/future and intertextuality/autonomy. In terms of subjective experience, this change further increases the complexity of the reflections and revelations that arise in these solitary silences, which, in terms of narrative form, increases the force these moments gather and the immediate changes they cause within the narrative's progression.

[49] Gaddis, "Landscape of History", 1.

[50] James's "Bronzino" is thought to be the portrait of Lucrezia Panciatichi by Agnolo Bronzino, c. 1540.

[51] In "Being Possessed and Possessing", Millicent Bell suggests that intertextuality may be at play here: she points out a similar moment in Nathaniel Hawthorne's *The Marble Faun* (105).

CHAPTER II: "CONSPIRACIES OF SILENCE"

Donatella Izzo sees the world of *The Wings of the Dove* as "thoroughly saturated with capital and with the power games that keep it in circulation".[52] Her umbrella term for such power games is "blackmail": imbalances in knowledge cause imbalances in power – and in terms of novelistic form, these imbalances generate narrative development.[53] Power relations are maintained by silence and in *The Wings of the Dove*, Izzo claims, "the sounds of silence take center stage as vehicles of knowledge, understanding, and communication".[54] Silence may not occur as frequently in *The Portrait of a Lady*, but it remains an important manifestation of the novel's power system. This chapter examines the enactment of silence through nonverbal communication, exploring the ways in which silence is used to impact on subjectivity. These enactments require "reading" someone else's silence as well as registering the effects of one's own. Nonverbal communication comprises a wide range of modalities, including dress, olfaction, and use of personal space; this study limits itself to bodily movements ("gestures and other body movements, including facial expression, eye movement, and posture") and paralanguage (tone, hesitancy).[55] These modalities can be used to shield or reveal information, thereby manipulating the perception of situations. Yet they sometimes thwart one's intentions. For example, James presents "conspiracies of silence" as theatrical performances, where nonverbal communication can break the willing suspension of disbelief as well as create it. While *The Portrait of a Lady* revolves around three conspiracies of silence that propagate narrative progression successively, all conspiracies of silence in *The Wings of the Dove* emerge around the same point in time, early on in the narrative, and work together (and against each other) to create the narrative arc.

In *The Portrait of a Lad*y, the face is the focal point of these conspiracies – characters wear "masks" that are cracked when their eyes visibly display unuttered meanings or their voices unintentionally hit the wrong tone. The first conspiracy of silence that transpires in the novel, between Ralph and Mr Touchett, bestows upon Isabel an inheritance so large that she is free to go wherever she would like. Ralph had pleaded for it with his father: "She's entirely independent of me; I can exercise very little influence upon her life. But I should like to do something for her" (PL, 164). Although Ralph claims that he wants to augment "her power", so that she will be one of those people who is "able to meet the requirements of their imagination", he comes to admit that he is acting mostly for his own "mere amusement", hoping she will meet "the requirements of [his] imagination" (PL, 164; 165; 167). Sandeen considers Ralph closely affiliated with James, designing Isabel's prospects like an author within the story.[56] Fitting with James's elliptical style, the actual moment in which Isabel inherits the money is omitted. When Isabel later asks Ralph "Face to face" whether he knew about the contents of his father's will, he "gazed a little more fixedly at the Mediterranean" (PL, 195). Ralph's cover-up proves successful, quite simply because he averts Isabel's gaze. As Butte notes, "The gaze is such a good and typically Jamesian moment because it immediately suggests issues of masquerade and performance that become even more labyrinthine in their deeply intersubjective forms".[57] Interestingly, the theatricality of this particular conspiracy of silence lies with its victim, Isabel, rather than its perpetrator. This is not simply because Ralph considers Isabel's situation in itself a "performance" that he is "determined to sit out", but because the married Isabel reciprocates his conspiracy of silence with one of her own, the theatrical qualities of which Ralph recognises (PL, 339). Although Ralph feels "shocked and humiliated" by Isabel's marriage, knowing Osmond to be a fortune-hunter, he is also intrigued how ever since "she would always wear a mask" (PL, 292; 336). Isabel, in turn, is aware she is "playing a part before her cousin", "perpetually, in their talk, hanging out curtains", and believes herself to so be doing Ralph a "kindness"; however, she does not sense that he can see that she is acting (PL, 371). When she betrays herself momentarily by crying out for help – "Her mask had dropped for an instant…He had caught a glimpse of her natural face and he wished immensely to look into it" – Ralph realises that his wish to fully break her silence is "for his own satisfaction more than for hers" (PL, 396-7). This passage indicates that Ralph has a clearer view of both their investments in Isabel's conspiracy of silence than she does herself. On Ralph's deathbed, when he admits that he has made Isabel rich and she admits her misery in marriage, "nothing mattered now but…the knowledge that they were looking at the truth together" (PL, 487). Both Ralph and Isabel feel the need "to say everything", to fully resolve the conspiracies of silence between them to arrive at an equal standing and achieve peace of mind (ibid). Ralph's conspiracy demonstrates that one silence can initiate a chain reaction of silences, and that there are differences in the success with which these silences are accomplished as well as in the authority with which they are exercised.

Indeed, Madam Merle, who instigates and regulates the second major conspiracy of silence, does so with "an expressive, communicative, responsive face" and therefore with much more sophistication than Isabel's "fixed and mechanical" mask ever manages to (PL, 157; 336). According to Stafford, even James himself considered Madam Merle a most enigmatic character.[58] She certainly may be "too flexible…too ripe…[existing] only in her relations", but she does not prove infallible in her interactions (PL, 171-2). That is, she does betray her investment in Osmond and Isabel's marriage – and breaks this silence not in words, but through the tone of her voice and the look in her eyes. Occasionally, "she dropped a remark of ambiguous quality, struck a note that sounded false", but she begins to more fully shed light on her secret investments when Isabel fails to arrange Pansy's marriage to Lord Warburton, revealing "a dangerous quickness in her eye and an air of irritation which even her admirable ease was not able to transmute" (PL, 272; 436). Yet Madam Merle's true betrayal of her secret is contiguous with the betrayal of her realisation that Isabel knows her secret, thereby amplifying the drama of the moment. How this realisation comes about, how Madam Merle recognises "an entirely new attitude on the part of her listener", remains unclear, as the moment is narrated from Isabel's point of view – moreover, it seems unimportant (PL, 467). What is crucial is that Isabel marks "a sudden break of her voice" and recognises what realisations are transpiring for Madam Merle in each "space of an instant", in each silence that breaks the "conscious stream of her perfect manner" (ibid). Isabel long displays a naïveté toward her social environment, but in the course of the narrative she becomes finely attuned to artfulness in social behaviour and, like Ralph, manages to grasp the meanings displayed behind a mask.[59]

In Osmond, Madam Merle has an accomplice against Isabel who far outshines herself; Osmond's social image, which he upholds so carefully, is built entirely on a foundation of silence. This is clear not simply from his choice as a widower to live removed from society on the top of a hill, or from the Thursday open evenings at his marital home, which he holds "to tantalise society with a sense of exclusion, to make people believe his house was different from every other", but more generally from "His ambition…not to please the world, but to please himself by exciting the world's curiosity and then declining to satisfy it" (PL, 337; 338). It is deeply ironic, of course, that Isabel, when falling in love with him, notes that "It was not so much what he said and did, but rather what he withheld, that marked him for her" (PL, 229). In marrying Isabel, Osmond does not simply participate in Madam Merle's conspiracy, but subjects Isabel to constant coercion through his silence, thereby never giving her anything tangible with which to accuse him. With "deepening experience", however, she learns to understand the underlying meaning of his remarks and read his facial expressions "as she would have read the hour on the clock-face" (PL, 366; 370). Osmond's refined enactment of silence stems from it being part of his "habitual system", and it is therefore not visibly artful

[52] Izzo, "Sounds of Silence", 101.

[53] Ibid., 104.

[54] Ibid., 106.

[55] Starkey, "Nonverbal Communication", 8.

[56] Sandeen, "James's Later Phase", 1061.

[57] Butte, "Deep Intersubjectivity", 135.

[58] Stafford, "The Enigma of Serena Merle", 119.

[59] A number of critics see Isabel's naïveté as part of her personifying America. For example, Fogel, in "Framing James's Portrait", writes that "it is Isabel herself who above all embodies the strengths and weaknesses of America – its innocence, its honesty, its good intentions, but also its narcissism, its lack of a historical sense, and its ignorance about the essential structures of civilization" (3).

to a novice onlooker (PL, 406). Its standard formulas are, however, easy to interpret for someone like Isabel who endures constant exposure to them, and this entails paradoxical consequences: on the one hand, heightened understanding increases Isabel's sense of suffering, while on the other, it allows her "to prepare her answer" and thereby increases her sense of agency (PL, 357).

Osmond, along with Madam Merle, manages to lure Isabel into the third prominent conspiracy of silence of the novel, geared against his daughter Pansy, which simultaneously creates an opportunity for Isabel to resist him. Osmond has trained Pansy to be silent, to have no will of her own ("She was evidently impregnated with the idea of submission") so that she will be an eligible candidate for an extravagant marriage (PL, 207). As Osmond exclaims to Isabel: "My daughter has only to sit perfectly quiet to become Lady Warburton" (PL, 359). Osmond also commissions Isabel to remain quiet toward Pansy about Warburton's interests until he proposes to her, but Isabel is plagued by the idea that Warburton might desire the marriage only to be closer to herself, and that Pansy has no actual interest in him either. She confronts both Warburton and Pansy very tentatively. With the former, a complex exchange of looks proves to her that he suspects she might be "uneasy on her own account", but she denies him any suspicion of her "detecting in his proposal of marrying her stepdaughter an implication of increased nearness to herself" (PL, 380). "In that brief, extremely personal gaze, however, deeper meanings passed between them than they were conscious of at the moment", anticipating a point in time in which they will arrive at some transcendent realisation about this exchange (ibid). This passage exemplifies Moses's theory of suspended realisations and actions in James. Isabel's exchange with Pansy, in contrast, is more immediately surprising. Isabel is forced to "interrogate without appearing to suggest" and in offering answers that are in line with Osmond's commission, it feels to Isabel "as if her face were hideously insincere" (PL 398; 400). Pansy, however, pours her heart out, declaring that Warburton knows she has no interest in him, so that "there's no danger" (PL, 401). Not only does Pansy here demonstrate an unexpected profundity of character and sensibility ("Isabel was touched with wonder at the depths of perception of which this submissive little person was capable"), but she concurrently relieves Isabel from her anxieties about thwarting Osmond's conspiracy of silence (ibid). Pansy manages to ward off Warburton herself – ironically, given her father's training – by hardly uttering a word: it is her body language and the way she looks at Warburton that finally convince him that it be better to head back to England.

In *The Wings of the Dove*, James seems to build on Pansy's form of communication by allowing power relations to be played out even more elaborately and forcefully in gestures as well as gazes. Practically all characters in the novel are both victims and perpetrators of conspiracies of silence, but the number of conspiracies contrived against Milly stands unparalleled. The conspiracies against Milly are entangled from early in the novel onwards, but the one with most vicious motivation issues from Kate and Densher's hand. Silence is introduced as constitutive of Kate and Densher's relationship, instrumental to their falling in love: "It wasn't, in a word, simply that their eyes had met; other conscious organs, faculties, feelers had met as well" (WD, 48). Their affair is finally triggered during a chance meeting on the London Underground, where "they could only exchange the greeting of movements, smiles, silence" (WD, 49). Through their strictly nonverbal communication, Kate and Densher's relationship develops at a much higher speed than would have occurred if they had talked to each other – the Underground stations they pass become a metaphor for the speed and distance their relationship gathers, to the point that they alight from the Underground carriage together, essentially as a couple. There is something dangerous about the way their relationship begins, established as it is like a bolt from the blue.

Silence between Kate and Densher becomes the locus of inequality following Kate's set up of the conspiracy against Milly: Kate is the "distinguished actress", with "Densher relegated to mere spectatorship, a paying place in front, and one of the most expensive" (WD, 209). His investment in the conspiracy is, after all, just as large as Kate's, even though he is not in charge. The reason Kate wants to run the show is because Densher gazes at her with such a "complacent eye", something Milly is bound to notice (WD, 205). Unlike Kate, Densher cannot expel meaning from his looks, but he personally values this form of communication. He places rather too much trust in the equal exchange of knowledge in the gaze, assuming that "between himself and Kate, things were understood without saying, so that he could catch in her, as she but too freely could in him… the whole soft breath of consciousness meeting and promoting consciousness" (WD, 293-4). Consciousness, to Densher, is intersubjective and "freely" and easily accessible to both parties. He believes that all their gestures and glances are "sublimely sincere" and encompass a density of meaning that no words could possibly do justice to: "The long embrace in which they held each other was the rout of evasion…It was stronger than an uttered vow" (WD, 200-1). As Kate abuses his trust in silent communication to the full, it takes Densher a very long time to understand what exactly she is trying to achieve by making him court Milly. He is deeply troubled once he does understand her whole plan, but Kate still manages to hold power over him:

Her smile itself, with this, had so settled something for him that he had come to her pleadingly and holding out his hands, which she immediately seized with her own as if both to check him and to keep him. It was by keeping him thus for a minute that she did check him; she held him long enough, while, with their eyes deeply meeting, they waited in silence for him to recover himself and renew his discretion (WD, 244).

This passage lucidly relates how Kate controls all sequences of actions and reactions: a remark of Densher's on the depth of their relationship, elicited by Kate → Kate's smile → Densher offering his hands → Kate holding his hands → their gaze → renewed discretion on Densher's part. However, the submissiveness Kate thus instils in Densher eventually backfires on her: he becomes doubtful of her emotional investment in their relationship and demands she prove his love to him by staying the night. Densher further gains in power by receiving Milly's inheritance, allowing him to set the terms for their relationship: Kate can choose him or the money.[60] "'We shall never be again as we were!'" Kate declares as she turns away from him, recognising how their power relation has been overturned (WD, 422). [61]

Milly's inheritance also, belatedly, overturns the power relation between Kate and Milly, the reigns of which are held by the former during the latter's lifetime. Milly is particularly intrigued by the vision of Kate – both the way she looks at others and the way she is looked at. Once Milly is led to believe that Densher is in love with Kate, but that she does not return his feelings, Milly is plagued by the question: "'Is it the way she looks to him?'" (WD, 146). This interest reaches its climax when Milly experiences a "mute exchange" with Kate, looking down upon her "from the balcony" (WD, 163). She sees Kate as "the peculiar property of someone else's vision…Just so was how she looked to him, and just so was how Milly was held by her – held as by the strange sense of seeing through that distant person's eyes" (WD, 164). The qualities of this "strange sense" and the moment's effects remain quite obscure, but it seems as if Milly recognises in Kate's gaze the power she wields over Densher, and subsequently wants to prevent herself from seeming "plaintive", from surrendering to Kate too – "She would never in her life be ill", she decides, thereby creating her own conspiracy of silence (ibid). Soon after, however, Milly willingly lets Kate manipulate her perception of an unstable situation. In the National Gallery, Milly is surprised to see Densher, and she stares at him before she realises that her staring is observed by Kate. This "perception intervened… surpassed the first in violence", as Milly feels caught in displaying the profound effect Densher's presence has on her (WD, 184). Milly then realises that Densher wasn't alone. Kate's face specifically said so, for after a stare as blank at first as Milly's it broke into a far smile…[an] instant reduction to easy terms of the fact of their being there, the two young women,

[60] In "James's Opaque Style", King notes: "What Densher gains through his exposure to Milly is a sense of his own authorial power. It is on the cards that he can 'kill'…her, but his refusal to read the writing she leaves behind also permits him to recreate her. The burned letter kindles his imaginative power" (7).

[61] In "James's Opaque Style", King argues that Kate's "extraordinary mix of forceful presence and absolute powerlessness makes her one of the clearest exemplars of James's ambivalence about the female authority he wants to explore but also restrain" (7).

together…A minute in fine hadn't elapsed before Kate had somehow made her provisionally take everything as natural (WD, 184-5).

Kate, by virtue of knowing what is at stake for every participant in this triangle of gazes, manages to govern the situation with a simple smile, subjecting Milly and Densher to the meaning she chooses to give it. Milly understands that "something wonderful and unspoken was determinant" on all their parts, "and the way they let all phrasing pass was presently to recur to [Milly] as a characteristic triumph of the civilised state" (WD, 185). Milly allows herself to be "handled" by Kate, thereby happily abstaining from probing Kate and Densher's reasons for being there together, because too much is at stake for herself in this moment: her gaze has lifted a veil from her most private feelings (ibid).

Kate and Densher's "conspiracy of silence" reaches its full maturity in Venice synchronously with that of Milly's own, who has built around her "an impenetrable ring fence, within which there reigned a kind of expensive vagueness made up of smiles and silences and beautiful fictions and priceless arrangements, all strained to breaking" (WD, 361). Everyone knows that Milly is mortally ill, but she nevertheless attempts to dissolve their consciousness of the fact. The tension between Kate and Densher's conspiracy and that of Milly manifests itself most powerfully in Kate and Milly's relationship, which is compared to "some dim scene in a Maeterlinck play" (WD, 270). Paradoxically, they are both attempting to manipulate the other's perception of themself by feigning honesty: "It was when they called each other's attention to their ceasing to pretend, it was then that what they were keeping back was most in the air" (ibid). Kate and Milly both know that they are play-acting, yet when alone, when they leave their roles behind, they deny each other a view of their true characters. Nevertheless, Kate has the edge in these private exchanges, because she can guess much better what Milly might be keeping from her. When Milly finally discovers Kate's secret, she cannot face the atrocity of her deeds in words – Milly's sentiments are most astutely caught in Mrs Stringham's image: "'She has turned her face to the wall'" (WD, 345).

More than in *The Portrait of a Lady*, *The Wings of the Dove* displays power relations not only through conspiracies of silence, but also within and between these conspiracies, and it does so by letting them evolve together throughout the narrative rather than letting them follow each other up consecutively. The ways in which the conspiracies are played out are also more intricate in the later novel, as James employs a wider range of nonverbal communication: gazes and tones are now complemented by smiles, grasps, embraces, and turns.

CONCLUSION

In both *The Portrait of a Lady* and *The Wings of the Dove*, silence assumes the form of a space that is lived through, enclosing and revealing subjective experiences. James's metaphors in his preface to *The Wings of the Dove*, architectural block and medal, both emphasise that the spatial and temporal dimensions of subjectivity need to be balanced to create a sense of unity and completion in fiction. Silence caters to this need as a narrative technique that opens up the story transpiring between the lines, the crucial spells of realisation and communication that impact on the development of characters and the larger narrative, by virtue of encompassing a density of meaning that acts of speech cannot contain. This thesis has shown how during solitary silences, *The Portrait of a Lady* plays on the dichotomy between private and public places: in drawing rooms these silences have a deeply personal impact and cause a strain within the narrative arc, whilst in the public places of Rome they make relativizing connections with the past possible and thus create a sense of relief for the subject and the larger narrative. *The Wings of the Dove* consistently evokes a sense of historical continuity during comparable silences; the weight of history combined with the prospect of the future alters Milly's inclination toward life and institutes an impulse in the narrative's progression. In addition, silence constructs and reveals the subjective experience of power relations. In this context, nonverbal communication variably mobilises and disrupts conspiracies of silence. The narrative of *The Portrait of a Lady* follows a chain reaction of such conspiracies that demonstrate differences not only in the sophistication with which characters employ nonverbal communication to manipulate the perception of situations, but also in characters' ability to "read" the nonverbal communication of others. Conspiracies of silence in *The Wings of the Dove* do the same, but in more complicated ways: the novel stages the internal frictions, entanglement, synergy and clash of these conspiracies, along with a wider range of nonverbal communication methods. These changes heighten the sense that deception imbues all manifestations of social interaction in the novel. On a conceptual level, then, silence makes room for considering the construction of subjectivity outside of traditional critical approaches, which have tended to focus on its relation to consciousness: silence unfolds how subjective experiences and the changes these bring about are reflected formally in the text. James's silences open up many paths to explore in the future, including the forms and functions of silence in Victorian realist fiction, which could foster understanding of the differences between realist and modernist conceptions of subjectivity.

WORKS CITED

Ballam, John D. "Henry James and a 'Sense' of Place: The Modalities of Perception." *The Henry James E-Journal 8* (2004): N. pag.

Bell, Millicent. "The Dream of Being Possessed and Possessing." *The Massachusetts Review* 10.1 (1969): 97-114.

Berkman, James S. "Eliot Rewritten, James Revisited: A Streak of Roman Sunlight Reveals the Real Inspiration for *The Portrait of a Lady." The Henry James E-Journal* 13 (2009): N. pag.

Blackwood, Sarah. "Psychology." In *Henry James in Context*, ed. David McWhirter, 270-9. Cambridge: Cambridge University Press, 2010.

Borch, Christian. "Interview with Edward W. Soja: Thirdspace, Postmetropolis, and Social Theory." *Distinktion: Scandinavian Journal of Social Theory* 3.1 (2002): 113-20.

Boyle Machlan, Elizabeth. "'There Are Plenty of Houses': Architecture and Genre in *The Portrait of a Lady.*" Studies in the Novel 37.4 (2005): 394-410.

Butte, George. "Henry James and Deep Intersubjectivity." *The Henry James Review* 30.2 (2009): 129-43.

Collins, Martha. "The Narrator, the Satellites, and Isabel Archer: Point of View in *The Portrait of a Lady." Studies in the Novel* 8.2 (1976): 142-57.

Despotopoulou, Anna. "The Price of 'Mere Spectatorship': Henry James's The Wings of the Dove." *The Review of English Studies* 53.210 (2002): 228-44.

Emerson, Donald. "Henry James and the Limitations of Realism." *College English* 12 (1966): 161-6.

Fischer, Sandra K. "Isabel Archer and the Enclosed Chamber: A Phenomenological Reading." *The Henry James Review* 7.2-3 (1986): 48-58.

Foeller-Pituch, Elzbieta. "Henry James's Cosmopolitan Spaces: Rome as Global City." *The Henry James Review* 24.3 (2003): 291-7.

Fogel, Daniel Mark. "Framing James's Portrait: An Introduction." *The Henry James Review* 7.2-3 (1986): 1-6.

Gaddis, John Lewis. *The Landscape of History: How Historians Map the Past.* Oxford: Oxford University Press, 2002.

Hale, Dorothy J. "Henry James and the Invention of Novel Theory." In *The Cambridge Companion to Henry James,* ed. Jonathan Freedman, 79-101. Cambridge: Cambridge University Press, 1998.

Hartley, David. *Observations on Man, his Frame, his Duty, and his Expectations.* 1749. Warrington: W. Eyres, 1801.

Izzo, Donatella. "Sounds of Silence in *The Wings of the Dove* and *Blackmail*." In *The Men Who Knew Too Much: Henry James and Alfred Hitchcock*, eds. Susan M. Griffin and Alan Nadel, 97-111. Oxford: Oxford University Press, 2012.

James, Henry. "The Art of Fiction." 1884. In *The Critical Muse: Selected Literary Criticism,* ed. Roger Gard, 186-206. Harmondsworth: Penguin, 1987.

---. *The Portrait of a Lady*. 1908. London: Wordsworth, 1999.

---. Author's Preface to *The Portrait of a Lady*, by Henry James, 3-15. London: Wordsworth, 1999.

---. *The Wings of the Dove.* 1909. London: Wordsworth, 2009.

---. Author's Preface to *The Wings of the Dove*, by Henry James, 3-17. London: Wordsworth, 2009.

---. *The Letters of Henry James, Volume I.* Ed. Percy Lubbock. New York: Charles Scribner's Sons, 1920. Accessed 4 May, 2013. http://www.gutenberg.org/files/38776/38776-h/38776- h.htm

---. *The Letters of Henry James, Volume II*. Ed. Percy Lubbock. New York: Charles Scribner's Sons, 1920. Accessed 4 May, 2013. http://www.gutenberg.org/files/38035/38035-h/38035- h.htm

Kelly, Lionel. Introduction to *The Portrait of a Lady,* by Henry James, v-xv. London: Wordsworth, 1999.

King, Kristin. "Ethereal Milly Theale in *The Wings of the Dove*: The Transparent Heart of James's Opaque Style." *The Henry James Review* 21.1 (2000): 1-13.

Kuchar, Gary. "Henry James and the Phenomenal Reader: Consciousness and Variation of Style in *The Wings of the Dove." The Henry James Review* 21.2 (2000): 170-85.

Labrie, Ross. "Henry James's Idea of Consciousness." *American Literature* 39.4 (1968): 517-29.

Lamm, Kimberly. "A Future for Isabel Archer: Jamesian Feminism, Leo Bersani, and Aesthetic Subjectivity." *The Henry James Review* 32.3 (2011): 249-58.

Marshall, Gail. "Performances in *The Portrait of a Lady." The Henry James Review* 31.3 (2010): 264-70.

Mezei, Kathy and Chiara Briganti. "Reading the House: A Literary Perspective." *Signs: Journal of Women in Culture and Society* 27.3 (2002): 837-46.

Moses, Omri. "Henry James's Suspended Situations." *Modern Philology* 108.1 (2010): 116-50.

"Mr. Henry James's New Book." In Henry James, The Wings of the Dove: A Norton Critical Edition, eds. J. Donald Crowley and Richard A. Hocks, 481-3. New York: W. W. Norton, 1978. Originally published in *Times Literary Supplement* (London: September 1902).

Pippin, Robert B. *Henry James and Modern Moral Life*. Cambridge: Cambridge University Press, 2001.

Reynolds, Nedra. *Geographies of Writing: Inhabiting Places and Encountering Difference.* Carbondale (IL): Southern Illinois University Press, 2004.

Richmond, Marion. "The Early Critical Reception of The Portrait of a Lady (1881-1916)." *The Henry James Review* 7.2-3 (1986): 158-63.

Sabiston, Elizabeth. "Isabel Archer: The Architecture of Consciousness and the International Theme" *The Henry James Review* 7.2-3 (1986): 29-47.

Sandeen, Ernest. *"The Wings of the Dove* and *The Portrait of a Lady:* A Study of Henry James's Later Phase." *PMLA* 69 (1954): 1060-75.

Stafford, William T. "The Enigma of Serena Merle." *The Henry James Review* 7.2-3 (1986): 117-23.

Starkey Jr., Duncan. "Nonverbal Communication." *Psychological Bulletin* 72.2 (1969): 118-37.

Stowe, William. "James's Elusive Wings." In *The Cambridge Companion to Henry James,* ed. Jonathan Freedman, 187-203. Cambridge: Cambridge University Press, 1998.

Tintner, Adeline R. "'In the Dusky, Crowded, Heterogeneous Back-Shop of the Mind': The Iconography of *The Portrait of a Lady." The Henry James Review* 7.2-3 (1986): 140-57.

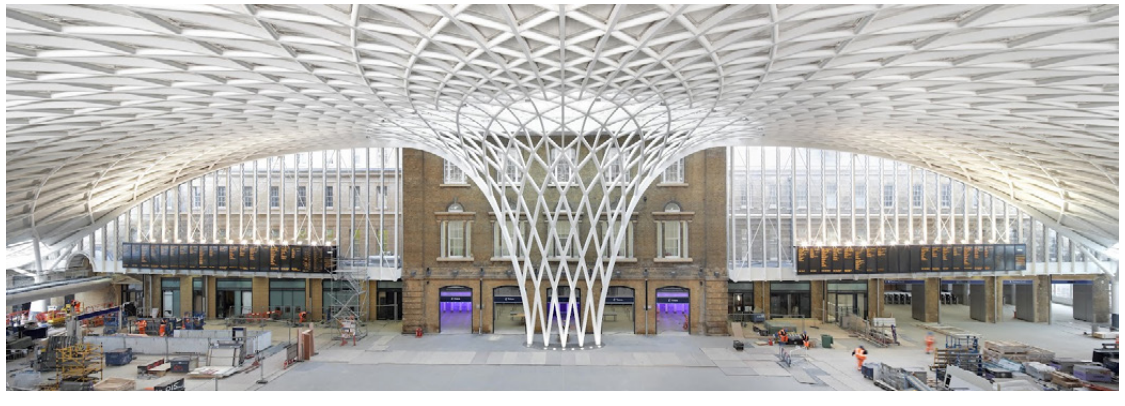
Watson, George. "The Lost Prophet of Realism." *The Sewanee Review* 96.3 (1988): 485-92.

White, Allon. *The Uses of Obscurity: The Fiction of Early Modernism.* London: Routledge, 1981.

Wordsworth, William. *The Prelude.* London: 1850. N. pag. *Bartleby.com*. Web. 28 Apr. 2013.
Yeazell, Ruth B. "Talking in James." PMLA 91.1 (1976): 66-77.

The Need for Physical Co-Presence: Investigating the Role of Physical Space at the HUB Kings Cross

Lucia Rost



ABSTRACT

In today's world of increasing online communication, the meaning of physical space needs to be re-discussed. Early observers of the 'virtual age', such as Giddens (1991) and Castells (2000), argued that space has lost its importance due to processes of globalisation and virtualisation. However, there seems to be evidence of a persisting need for physical co-presence on a micro level of experience that has only gained limited scholarly attention, but would be relevant to investigate from an individual, professional and academic perspective. Resulting from four weeks of participant observation and interviews at the HUB Kings Cross, this research investigates the role of physical space today. The HUB is a recently founded and growing global organisation that provides physical spaces where people from different professions can work together. In line with grounded theory, this research uses theories by Goffman (1951), Collins (2004) and other scholars to explain the findings at the HUB that people sought physical co-presence of other people because it increased their productivity, raised their level of emotional energy and enabled them to build up trust in others. The findings at the HUB, together with the fact that an increasing number of HUBs and co-working spaces are opening worldwide, support the claim that physical space plays an important role in an increasingly virtual world and suggests further investigations of models that integrate communication technology and respond to the need for physical co-presence.

INTRODUCTION

Today, we can talk to people on the other side of the world, we can share files and screens with them, look at them through webcams; we can work together with people from different countries; we can get advice online, shop online, play games online, study online; we can create avatars that interact in virtual worlds and we can use smileys and 'online language' to interact with our friends: "Technology will always do what we want it to do. The question is … do we want that?" (Harry).[1]

At the HUB Kings Cross in London, social entrepreneurs, web developers, real estate agents and other people come together to work in a shared physical space. They work on their laptops, Skype with business partners around the world, talk to clients on the phone but they do all this in the physical co-presence of other people. Why do these people go to the HUB? What is it that makes them "pay 300-400 pounds to come down to the HUB just to enjoy the atmosphere, to be with other people" (Thomas)? Through my research at the HUB Kings Cross, I will investigate the role of physical space in today's increasingly 'virtual world'. Why do people at the

[1] Quotations are taken from interviews conducted by the author at the HUB Kings Cross in January 2013.

HUB seek the co-presence of other people? When is physical co-presence still important for them? What makes physical interactions distinct from online interactions? What role does physical space play with regard to someone's professional and social life? Although much has been written about the impact of globalisation on the meaning of local physical space (e.g. Giddens, 1991; Kearney, 1995; Castells, 2000; Caldwell & Lozada 2007), there seems to be a lack of studies about individuals' everyday life experience of physical co-presence on a micro level. Understanding the role of physical co-presence is not only relevant for interdisciplinary academic debates but also interesting from a more practical perspective. In an increasingly virtual world, it is important for individuals to understand in what way physical space matters to them. Being aware of the effects of physical co-presence could be helpful for using physical space more consciously and beneficially. In terms of work, such an understanding could, for instance, help in the development of effective co-working spaces.

In order to investigate the role of physical space today, I spent four weeks in London at the HUB Kings Cross, a networking space for social entrepreneurs and others, where I conducted participant observation and interviews with 20 members. The first HUB was opened in London in 2005 and now there are about 30 HUBs, and 50 in the making around the world, that are connected through an online network. More importantly than online networking, the HUB stresses the significance of connecting people physically and sees physical spaces as "keys to their impact" ('The HUB: Inspiring Spaces', 2013). When interviewing people at the HUB, I was aware of the fact that they were a selective group of people who valued physical co-presence. However, I selected the HUB as a setting because I saw its recent foundation and growing expansion as an interesting phenomenon pointing to a certain trend of valuing co-presence, and I was interested in finding out more about this new model and the members' reasons for joining the HUB. The research shows that people at the HUB value physical co-presence because it helps them to be productive, contributes to their energy levels and makes it easier to establish trust in others.

In order to explain these findings at the HUB, and to investigate the role of physical space today, I use the methodology of grounded theory and apply different sociological theories to the findings. I offer a brief overview about the role of physical space in the past and today and provide a theoretical framework for the three main aspects identified in interviews—productivity, emotional energy, and trust. After elaborating on the methodology, I apply theory to the qualitative data gathered at the HUB. As for productivity, I use Goffman (1959), who says that people adopt a certain role when surrounded by other people and that they always perform on a front stage, while they prepare the next performance on a backstage. At the HUB, people seem to perform a 'HUB role' that helps them to be productive. However, the findings at the HUB suggest that the distinction between front and backstage seems to be less clear today, more than 50 years after Goffman published his ideas. The HUB does not have a proper backstage and people create 'sub-spaces' rather than backstages.

Secondly, the increased energy that interviewees reported feeling when sharing a physical space can be explained by Collins' (2004) model of interaction rituals. Collins argues that interaction rituals produce emotional energy and that bodily co-presence is an essential requirement for interaction rituals to take place. At the HUB, Collins' requirements for interaction rituals seem to be met, and I was able to observe some interaction rituals and their outcomes. Lastly, several scholarly articles (Giddens 1991; Fussel, Kraut, Brennan, and Siegel, 2002; Urry, 2003; Rocco, 2005; Möllerig, 2005; Bijlsma-Frankema & Woolthuis, 2005; Bødker & Christensen 2012) help to explain the finding at the HUB that physical co-presence makes it easier to build up trust. Both the existing literature and interviews show that physical co-presence helps to establish a common ground, to enable communication, mutual understanding, and the capacity to build relationships. All these factors in turn have positive effect on building trust.

2. THEORY

In this theory section, I will offer a brief overview about the changing role of physical space in the past and today and then focus on three theoretical orientations to explain the three main findings at the HUB.

2.1 THE CHANGING ROLE OF PHYSICAL SPACE

Literature shows that physical space has always been essential for social interactions in the past. Especially after the transition from hunter-gatherer societies to farming societies, the social world became structured around a fixed physical space (Zvelebil, 1986). Travelling was limited and people not only gathered resources, such as food and tools, from the physical space, but their social life was essentially related to it (Geary & Bjorklund, 2000). Religion also reinforced the value associated with physical spaces, since, according to Durkheim (1995), humans attached importance to space by dividing it into the sacred and the profane, and by performing rituals in the space that expressed values of the community.

Many scholars argue that throughout history physical space has lost its importance, especially due to processes of globalisation and the advancement of technology. Kearney (1995), for example, claims that globalisation reorganises the imagery of the basic world-view universals, space and time. Space has become multidimensional, meaning that it depends less upon horizontal relations of spatial integration and more on hierarchical links to the global system. As a consequence, he recognises the emergence of transnational spaces, diasporas, and hyperspaces, such as airports and virtual communities. Caldwell and Lozada (2007) also suggest that globalisation is increasingly "colonising" local spaces (503). They suggest that the 'loss of the local' is further increased through the emergence of internet networks that replicate traditional social relationships, but in a way that compresses time and space.

Castells (2000) argues that a new network society with new spatial structures has emerged due to a revolution in information technology in the late 20th century. He claims that new technologies allow "the formation of new social organisation and social interaction" (247). The "electronic hypertext" is the "backbone of a new culture", in the sense that people are linked through the Internet and virtuality becomes a fundamental component of their symbolic environment. Castells claims that technology also transforms the meaning of space in the sense that physical co-presence is no longer a requirement for interactions to take place, a phenomenon he calls the "death of distance" (250). In addition to traditional space of places that are locally bound, a new form of spaces, spaces of flows, has emerged (ibid.). Spaces of flows are composed of electronic circuits and information systems and physical spaces are only part of spaces of flow when they have symbolic meaning. Castells concludes that although physical locations continue to exist, people are increasingly dominated by processes generated from spaces of flows and physical spaces have lost their importance.

Giddens (1991) also argues for the decreased importance of physical space. He says that one of the three essential aspects that give modernity its dynamism is the separation of time and space. According to Giddens, in pre-modern times, time and space were connected through the "situatedness of place" (16). In other words, because social interactions took place in a fixed place at a fixed time, space and time were connected through this place. He argues that every culture has possessed modes of time and space reckoning, such as calendars and crude maps, that were connected to a fixed local place. However, in modern times, space and time are no longer linked to place, and have thus been torn apart and emptied. This phenomenon is expressed through the use of mechanical timing devices and global maps with no privilege of place. The emptying of space and time is reinforced through abstract systems, more specifically through symbolic tokens and expert systems. Money is the most obvious example of a symbolic token that contributes to the emptying of time and space because it is independent from time and space. The same applies to expert systems that use technical knowledge independently from time and space. In this sense, Giddens and other scholars believe that physical space has lost its importance in an increasingly global and abstract world.

However, many scholars from different academic fields have stressed the persisting importance of meeting in a physical space. Many sociologists, such as Durkheim (1995), Collins (2004), or Goffman (1951) have for instance argued for the importance of physical interactions in the sense that co-present interactions can produce collective effervescence (Durkheim) and emotional energy (Collins) and can shape individuals' behaviour

(Goffman). From a philosophical perspective, interactions with co-present others have also often been considered highly important. To give an example, Hannah Arendt (1998) claims that we only experience reality by articulating our thoughts in front of others: "Compared with the reality which comes from being seen and heard, even the greatest forces of intimate life—the passions of the heart, the thoughts of the mind, the delights of the senses—lead an uncertain shadowy kind of existence unless and until they are transformed, deprivatized and deindividualised, as it were, into a shape to fit the public appearance" (50). Moreover, many scientists also stress the persisting need for physical co-presence. Evolutionary scientists (e.g. Geary & Bjorklund, 2000; Cartwright, 2008;) argue, for instance, that humans have evolved to interact physically. They observe a shift from olfactory to visual dominance that made primates "neurologically wired" for face-to face interactions and they stress the importance of physical co-presence due to potential sexual contact and sociable gestures (Turner, 2002). From a psychological perspective, Klemmer, Hartman, and Takayama (2006) argue that, particularly for infants, "physical interaction in the world facilitates cognitive development" (2). But also for adults, co-present interactions are seen to improve cognition. For example, gestures used in physical interaction not only help to communicate thoughts that are not easy to put in words but also make cognition and realisation of those thoughts easier. Medical scientists (Rutledge et al., 2008; Sigman, 2009) have also argued for a need for face-to-face interactions, showing that a decline in face-to-face contact due to social media has led to growing health risks and has had an impact on morbidity and mortality. Lastly, research about virtual communication also stresses the importance of physical communication in the sense that it often suggests that virtual communication is most successful when it is closest to experiences in the physical world (Lee, Danis, Miller & Jung, 2001; Clases et al., 2004). In sum, it has been shown that the role of physical space has been challenged over time but that for scholars from different academic fields physical co-presence still seems to be of importance.

2.2 PRODUCTIVITY

Reasons for the importance of physical space mentioned in interviews at the HUB were productivity, emotional energy, and trust. Ervin Goffman's (1959) micro-sociological analysis of human behaviour in the co-presence of other people can be used to explain productivity at the HUB. In the Presentation of the Self in Everyday Life, Goffman argues that people put on a certain mask—a role that they are striving to live up to—when surrounded by others. In this sense, one can argue that physical co-presence might trigger a certain behaviour, such as productivity. Goffman claims that a role is expressed through verbal and non-verbal expressions that are always controlled in a calculative way, even if people might not be aware of it: "While in the presence of others, the individual typically infuses his activity with signs which dramatically highlight ... confirmatory facts" (26). As for non-verbal expressions, Goffman uses the term front that he divides in a visible part—appearance—and a non-visible part—manner. He argues that fronts tend to be selected not created; even if there is no established social role for a new task, people tend to use one that is already established. Goffman also says that given social fronts tend to become institutionalised and become the "collective representation" of certain groups (24). Although some individuals might be cynical about their role at first, after a while they will be less cynical because their role becomes an integral part of their personality. Role playing also involves supressing the "immediate heartfelt feelings" to establish harmony and to convey a view that others find acceptable (8). In order to avoid disruptions of performances, people use preventive, corrective and defensive practices (12). Moreover, they conceal actions that are inconsistent with their performance and make the audience believe that they are especially close to them.

Performances can also take place in a team. In this case, every team member enacts an individual role that contributes to projecting a certain team front to outsiders. In business, for example, Goffman says that "when outsiders are present, the touch of business-like formality is even more important" (69). Also, professional etiquettes are used "to preserve before clients the common front of the profession" (78-79). A team is like a secret society, uniting people from different social ranks that contribute differently to the overall performance. Despite differences, teams are often loyal; if one team member makes a mistake, other team members often suppress the desire to punish.

Goffman claims that in the Anglo-American society that is "relatively indoor", performances are often given in highly bounded regions (92). He distinguishes between front regions where performances are enacted and back regions where performances are prepared that are both separate to outside regions. On the front stage, control of the setting is very important because it gives the performing team or individual a sense of security. Setting tends to stay put: furniture, décor, physical layout, background items are all arranged intentionally to support the performance. This is why official performances usually do not take place at someone's home and in Western European countries, luxurious settings are often hired by people for special performances. More than control of the setting, performers also control standards through matters of politeness (manner) and decorum (appearance). By decorum Goffman refers to moral requirements and instrumental requirements. Moral requirements are rules regarding non-interference, non-molestation of others or respect for sacred places, and instrumental requirements are duties, such as care of property or maintenance of work level. Goffman argues that people take standards for granted until something happens; he gives the example of an office where informal talk is allowed until people start talking in another language. Other standards at work are for instance, "mode of dress, permissible sound level, proscribed diversions, indulgences, affective expressions" (96).

In the back region, people relax from past performances and prepare future performances. It is the place where "suppressed facts make an appearance" (97). On the back stage, "illusions and impressions are openly constructed", décor can be stored, actions and characters can be discussed, costumes can be adjusted, and a team can run through their next performance. Here, the performer "can drop his front" and "step out of character" (98). The behaviour on the backstage is very different to the behaviour on the front stage and involves, for instance, "smoking, rough informal dress, sloppy sitting and standing posture ... minor physical self-involvements, such as ... chewing, nibbling" (111). Goffman even observes a different informal backstage language of "reciprocal first naming, open sexual remarks ... use of dialect or substandard speech, mumbling, shouting ... humming" (111). According to Goffman, back stages are necessary for any performance and can be found in every building: "the line dividing front and back regions is illustrated everywhere in our society" (107). Goffman also argues that there are always problems when the backstage gets blurred with the front stage: "no social establishment can be studied where some problems associated with backstage control do not occur" (105). He relativizes the clear distinction between front and backstage and says that a particular section of a front stage can be turned into a backstage by invoking a backstage style: "The performers ... by acting there in a familiar fashion symbolically cut it off from the rest of the region" (112). To sum up, Goffman argues that when in the presence of others on a front stage, individuals enact certain roles that they prepare on a backstage. This theory will be used to explain the reported productivity at the HUB.

2.3 EMOTIONAL ENERGY

Interviewees also often mentioned that sharing a physical space with others increased their energy levels, a finding that may be explained by Randall Collins' (2004) theory about interaction rituals. In his book Interaction Ritual Chains, Collins argues that bodily co-presence is a requirement for an interaction ritual that produces emotional energy and solidarity. Collins identifies four necessary requirements for an interaction ritual to take place: firstly, people should be physically co-present, so that they can have an effect on each other through their bodily co-presence. Secondly, there should be clearly defined boundaries to outsiders. Thirdly, participants in an interaction ritual should have a mutual focus of attention upon a common object or activity. Lastly, they should share a common mood or emotional experience (48).

The most common type of interaction ritual is the conversation. In a conversational ritual, speakers and listeners both adjust their bodily movements to the rhythm of the conversations through, for instance, nodding the head, blinking eyes and other gestures (75). The turn-taking is highly coordinated and a successful conversational ritual does not have gaps, overlaps, or embarrassing pauses. Conversations are also synchronized through features of people's voices, such as pitch register and range, loudness, tempo, accent, and duration of syllables. In a conversation,

laughter can be commonly produced and can build up collective effervescence. Collins argues that conversations are formally ritualistic because they follow a certain scheme and substantively ritualistic because sociable conversations are often more about the activity, such as keeping up friendly contact, than about the content of the conversation (78).

If an interaction ritual is successful it can have four outcomes. Firstly, it can create group solidarity and a feeling of membership. Secondly, it can generate emotional energy among the participants, a phenomenon that Collins defines as "a feeling of confidence, elation, strength, enthusiasm, initiative in taking action" (49). Thirdly, an interaction ritual can create symbols that represent the group, such as emblems, visual icons, words, gestures, the use of the first name, a narrative, a third person that is mutually known, professional jargon, or a piece of insider information. Those symbols help to "prolong membership from one situation to the next" (84). Lastly, interaction rituals can generate feelings of morality, "a sense of rightness in adhering to the group", that makes members despise violations of group solidarity and group symbols. Collins argues that "life is structured around the contrast between successful and unsuccessful rituals" (51). People always seek situations that produce the highest amount of emotional energy and "motivation and symbolic charge" (51).

Bodily co-presence, as one of the requirements, plays an essential role in an interaction ritual. Collins agrees with Turner that humans are "neurologically wired" to respond to each other in bodily co-presence (78). Examining formal and natural rituals empirically, Collins concludes that co-presence is especially crucial for small-scale rituals. For large-scale formal rituals that are shown on TV, solidarity and emotional energy are sometimes produced when showing close faces, thus when "TV approximates bodily feedback" (56). Bodily feedback is also very important in rituals of victory, such as sports. Collins says that the bigger the victory the closer the bodily contact of the group members in the victory ritual, ranging from "slapping hands to body hugs to piling onto heaps of bodies" (57). Also, despite increasing access to TV, attendance of sports events has not declined, because people want to share enthusiasm and collective energy. The same applies to attendance at concerts, and participation in religious and political rituals. While large-scale remote communication can give some sense of ritual participation, this is more difficult for small-scale natural rituals. If people are not physically present there is a lack of feedback and "micro-details of experience" (54). Collins argues that communication is difficult and unsatisfactory if people are, for instance, talking through a conference call, because vocal expressions are only a part of what creates feelings of participation (55). For example, on the phone people are unlikely to partake in a refreshment activity, such as drinking coffee or alcohol, eating cake, or smoking, all of which add a sensory character to a social situation and are part of "bodily co-participation" (62). Collins states that Internet and email lack the flow of physical interaction and sees email as a utilitarian form of communication because it degrades relationships by abandoning ritual aspects. If social activities are more distant, people will feel less solidarity, less respect for shared symbols and less personal motivation (64). Therefore, Collins argues that, for instance, remote teaching or electronic shopping will not replace their more conventional models in the future. Altogether, Collins considers physical co-presence a necessary requirement for an interaction ritual that produces emotional energy and solidarity.

2.4. TRUST

The last finding, that people at the HUB found it easier to build up trust in physical co-presence, will be explained with theory that derives from different scholars. Trust is seen as especially important in modern society and physical co-presence is considered an important factor for the establishment of trust. On the one hand, many scholars have identified the importance of trust in modernity (Giddens, 1991; Putnam, 1995; Bødker & Christensen, 2003; Bijlsma-Frankema & Woolthuis, 2005). Giddens (1991) argues, for instance, that the absence of time and space reinforces the need for trust in modern societies. Abstract systems are too complex to be understood by individuals and too much embedded in everyday life so that people make the decision to trust. Bødker and Christensen (2003) also claim that trust is functional in the sense that trusting is more pleasing, less stressful, that it fosters cooperation and reduces the costs of surveillance and contributes to productivity, tolerance and innovativeness. Similarly, Bijlsma-Frankema & Woolthuis (2005) are convinced that trust has a positive effect on relationships, open communication, and problem solving.

On the other hand, it has been argued that trust becomes more problematic in a 'globalised world' where relationships are becoming more distant in the "metaphorical and geographical sense" (Bijlsma-Frankema & Woolthuis, 2005, 2). Putnam (1995) has shown that Americans have become less engaged in associations, such as political groups or church-related groups, and that this has decreased social trust. Bijlsma-Frankema & Woolthuis (2005) argue that large geographical distances, fast moving technologies, and virtual relationships make it harder to establish trust because physical proximity is essential for trust. Scholarly literature reveals several reasons why it is easier to build up trust in physical co-presence.

The first reason is that it is easier to develop a common ground that is seen as the "springboard of trust development" (12). Rocco (2005) defines common ground as the "sum of mutual knowledge, belief, and mutual supposition" between people (190). She argues that common ground is developed through community membership, linguistic co-presence, and physical co-presence but that physical co-presence is the most important factor and essential for the other two factors to be realised; physical co-presence makes people develop common ground through identifying more easily with a community and through allowing linguistically co-present face-to-face conversations. Physical co-presence also helps to develop a common ground because people can exchange objects (Rocco, 2005), create new similarities (Möllerig, 2005), and because they hear, see and experience the same things (Fussel et al., 2002). It has been argued that a common ground between people makes it easier to establish trust (Pettigrew, 1998; Möllerig, 2005; Uslaner, 2006). Pettigrew (1998) claims for instance that in order to build up trust, contact must be accompanied by "common goals" (66). Uslaner (2006) also suggests that people often join a group to have contact with people who are like themselves in order "to bond with people whom [they] can easily trust" (8).

The second reason why physical co-presence encourages the building up of trust is that it improves communication, which has a positive impact on trust. Studies have shown that communication is easier and more frequent for people when they are physically close (Rocco, 2005; Fussel et al., 2002; Urry, 2003). If people see each other, they can give feedback and coordinate conversations more easily, which helps to avoid misunderstanding and to solve problems (Fussel et al., 2002; Urry, 2003). Communication is also seen as easier in co-presence because of non-verbal interactions (Fussel et al., 2002; Urry, 2003; Rocco, 2005; Bijlsma-Frankema & Woolthuis, 2005). Fussel et al. (2002) argue that using gestures, such as pointing and paralinguistic expressions (e.g. facial expression or intonation), increases the efficiency and quality of communication. Urry (2003) also suggests that "interactions are rich" when physically present because people can observe their body language, indexical expressions, facial gestures, status, voice intonation, pregnant silences, past histories, anticipated conversations and actions, turn-taking practices, and touch. Improved communication through non-verbal interactions is seen as having a positive effect on trust (Bijlsma-Frankema & Woolthuis, 2005). Urry (2003) states that especially eye contact "enables and stabilizes intimacy and trust" because it is the "most complete reciprocity of person to person" (164). Bødker and Christensen (2003) also say that bodily cues used for offline interactions represent some of the virtues that make people build up trust, such as dress, demeanour, and body language.

Related to improved communication, the third reason why physical co-presence has been said to have a positive impact on trust is that it fosters understanding and facilitates making judgments. If physically co-present, people can "read what the other is really thinking" (Urry, 2003, 163) and "develop mutual understanding" (Rocco, 2005, 12). They can also learn about the other person's competences and intentions (Bijlsma-Frankema & Woolthuis, 2005). For Urry (2003), the richness of interactions that enables mutual understanding explains why people still travel despite advanced virtual communication facilities. Thus, he defines a social network by the degree of meetingness, by how often a network meets up physically. Non-verbal interactions are also seen as contributing to an improved understanding in physical co-presence (ibid.). Improved understanding in physical co-presence, in turn, is seen as encouraging

trust between people (Woodworth, 2011, 42). Lastly, physical co-presence encourages people to build up personal relationships that are a good basis for trust. Several scholars have argued that it is easier to make more complex connections in physical co-presence (e.g. Urry, 2003; Bijlsma-Frankema & Woolthuis, 2005). Building up relationships in physical proximity is reinforced because of shared experience, non-verbal interactions, and mutual attention (Urry, 2003). Furthermore, Klemmer et al. (2006) argue that because there is more risk involved in physical interactions, meeting in a physical place represents a certain commitment that helps to develop a relationship. In turn, more personal relationships are seen as improving trust (Urry, 2003; Bijlsma-Frankema & Woolthuis, 2005). To sum up, literature about physical co-presence and trust has shown that it is easier for people to build up trust when physically co-present because of the perception of a common ground, better communication, easier understanding, and improved relationships.

This section has provided theoretical perspectives which place the research in the context of a debate about the meaning of physical space; they also provide a way to read and explain the findings at the HUB that suggest physical co-presence positively influences productivity, energy, and trust.

3. METHODS

Before applying the theory to the data at the HUB, I will elaborate on the research setting and methodology and I will also acknowledge potential biases.

3.1. RESEARCH SETTING

The empirical research was conducted at the HUB Kings Cross in London where I spent eight hours a day as a member host from 7 January 2013 to 1 February 2013. In this paragraph, I will provide a brief overview of the background of the HUB organisation, the people, and the space. The HUB is an organisation that connects social entrepreneurs according to the motto "innovation through collaboration" ('The HUB: About', 2013). The belief is that there is no shortage of good ideas to help solve today's social problems but that there is a lack of collaboration to realise the ideas. Therefore, the HUB connects people through an online network, events, and through providing physical spaces for people to work together. The three pillars of their philosophy are meaningful events, vibrant community, and inspiring spaces, and the three main values are "transparency, collaboration, and courage" (ibid.; Nathalie). The first HUB was founded in 2005 in London and now there are 30 HUBs around the world, with more than 5000 members, and more than 50 HUBs will open soon ('The HUB: About', 2013). In order to be able to use the space and online network, one has to pay a membership fee. There are different price categories depending on the frequency of using the space, the facilities one wants to use, and the member's income. The lowest amount for using the space at the HUB Kings Cross is £30 per month and the highest is £425 ('The HUB Kings Cross: Membership', 2013).

The HUB members come from different professional backgrounds, cultures, nationalities, and the HUB seeks "diversity in perspectives but similarity in values and intention" ('The HUB: Vibrant Communities', 2013). At the HUB Kings Cross, there are about 320 members, but only about 100 working in the space every day. The age ranges from about 20 to about 60 years and people seem well educated, social, and communicative. Although the HUB is meant to be for social entrepreneurs, there are also people working in other fields. Most members seem to be involved in social businesses and digital technology, but there are also members working in architecture, design, media, communication, consultancy, Arts, and education. There seems to be a balance of female and male members and the dress code ranges from mainly casual to occasionally formal.

Providing physical spaces is maybe the most crucial 'mission' of the HUB. The HUB sees physical spaces as "keys to their impact" and stresses that "in a time where everything is becoming virtual, we feel it is even more important for people to continue connecting physically in a meaningful setting" ('The HUB: Inspiring Spaces', 2013). The spaces are consciously designed to be open, flexible, inspiring, and communicative. The HUB Kings Cross is an old warehouse with three floors that are connected so that one gets the feeling that it is just one multi-layered room: the meeting rooms on the first floor have glass windows and can be seen from the ground floor and the second floor is arranged around a hole through which one can see the ground floor. As for flexibility, tables can be hung on the wall and people are free to write on many walls, including windows and even walls in the toilets. The design seems to reflect the creative and innovative ideas of people working there: the space includes unfinished brick walls, a glass ceiling, wooden tables, and colourful decoration.

The HUB Kings Cross: Ground Floor and First Floor (Cranston, 2011)

The HUB Kings Cross: Second Floor and Ground Floor (Cranston, 2011)

3.2 RESEARCH METHODS

My research is based on Glaser and Strauss' (1967) methodology of grounded theory. In order to fit the "empirical situation" and remain close to the data and interviewees, I "generate[d] theory from the data" (1). Instead of approaching the HUB with the purpose of verifying theory, I generated theory inductively from my experience and interviews at the HUB as illustrated in the theory section. I thought that the HUB would be an interesting setting for my research. Reading more about the HUB, having an interview with one of the managers, and exchanging ideas with my supervisor, Bart van Heerikhuizen, I decided to focus my research at the HUB on the meaning of physical co-presence. When I started my investigations at the HUB I did not have specific theory in mind; instead I wanted to explore the space and find out why people came to the HUB.

In the first week, I did mainly participant observation. I participated in the daily routine at the HUB and performed some tasks for the management, such as designing member profiles and analysing the data about current members. I also asked people informally why they decided to join the HUB and I wrote down observations and responses in my field notes. Doing participant observation helped me to become familiar with the setting and the people, and made it easier to understand their motivation (Bernard, 2006). After a few days, I reflected on my observations by structuring the field notes into different categories and subcategories.

In the second week, after a phone call with my supervisor Bart van Heerikhuizen, who gave me guidance on further steps, I drafted my interview questions with the field notes as a basis, and started interviewing people. For the interviews, I used Hermanowicz's (2002) article about semi-structured interviews. I divided the conversation into topical stages, starting with easier questions: 1) general questions about the work at the HUB, 2) questions about the physical space at the HUB, 3) questions about physical and virtual spaces more generally.[2] When conducting the interviews, I kept a certain formality, but still led them like a 'natural' conversation. I asked many spontaneous sub-questions and I took notes of keywords and asked them to elaborate on or explain some things. Sometimes, I reformulated a question or I summarised what they had said and asked if I had understood them correctly. I also "played the innocent" sometimes, asking them to explain things that seemed obvious to them and remained persistent when they tried to brush questions off (Hermanowicz,

[2] See appendix A2 for the interview questions.

2002, 486). Most of the time, people responded quite quickly, but sometimes they needed more time to think, and I always encouraged them to do so. I tape-recorded the interviews and typed them up afterwards. In total, I recorded 20 semi-structured interviews that lasted from 11 to 64 minutes, with an average of 28.3 minutes. I interviewed two people who were working for the HUB, three visitors, and the rest were permanent members. The staff members were chosen intentionally but the rest were chosen randomly. In order to have a more random selection, I often sat at an empty table and asked the person who came to sit next to me for an interview. I also did the same in the café area, and sometimes I approached people myself, especially the last two days, when I was concerned about interviewing as many women as men. The interviewees were between 20 and about 55 years old, and 10 of them were female and 10 male. They were mostly well educated and seemed interested in social sciences. Most of them worked for charities or social businesses (Emma, Sarah, Louise, Michael, Kate, Lucy), or in the field of digital technology (Peter, Christopher, Harry). Some were students (Sophia, Elizabeth, Lucy, Michael), working in the music industry (Anna, James), in property letting (Timothy, Jennifer), in education and capacity building (Robert, George), or they were either about to start or had recently started their own business (Thomas, Kate, Joanne). Since they came from different backgrounds, they often approached my questions very differently, depending on their personal interests.

In the third week, I wrote down common points from interviews, categorised them into main themes, and paid particular attention to those themes in the following interviews. In the beginning of the fourth week, I had another phone call with Bart van Heerikhuizen that helped to define the focus. After having gathered all the data, I decided to focus on the themes that were mentioned most often: productivity, energy, and trust. I then sought a theory to explain those findings.

3.3 CONCEPTUALISATION

When dealing with concepts that were mentioned by interviewees, I used the emic rather than etic approach, focusing on how "phenomena are perceived and interpreted" rather than on "scientific classifications" of concepts (Grenier, 1998, 42). In terms of Blumer's (1954) terminology, I did not use definitive concepts that give a "clear definition in terms of attributes or fixed bench marks" but instead I used sensitizing concepts that give a "sense of reference and guidance" and make people attentive for certain aspects (7). In other words, I used the definitions of concepts that interviewees used in my analysis to remain closer to their statements. With regards to productivity, for example, I did not refer to the common economic conceptualisation of productivity that focuses on the difference "between total real output product and total real factor input" (Bulkley & Van Alsytne, 2004). Instead I used an indigenous conceptualisation and approached productivity in the same way interviewees did, which can be seen as closer to the more general definition of productivity as "the quality of being productive or having the power to produce" (Grenier, 1998; Productivity, 2013).

3.4 PERSONAL BIAS

When conducting the research, I was aware of potential biases. First of all, I want to emphasise that the research could be biased by my own experience, background, preconceptions, expectations and interactions with other people. It is through my personal lens that I chose the setting, collected data, and selected what data and theory to use. I agree with critics who say that by choosing specific aspects to apply theory to, the grounded theory researcher runs the risk of ignoring other aspects (Charmaz, 2000 cited in Glaser, 2002). By focusing on productivity, emotional energy, and trust, I certainly left out other themes that could have been relevant. By leaving these themes out, I run the risk of spuriousness, in the sense that these themes could have influenced the causal relationships of physical co-presence and productivity, emotional energy, and trust (Neuman, 2011). I am certainly aware of such potential personal bias, but I have tried to remain as close to the interviewees and their statements as possible, using the methodology of grounded theory.

3.5 INTERVIEWEES' BIAS

Secondly, there is also the risk that interviewees' responses were biased. To begin with, the setting might have encouraged interviewees to give socially desirable answers (Neuman, 2011). Since the interviews were conducted at the HUB and I was also doing some work for the HUB, people might have felt under pressure to reproduce the positive narrative of the HUB. I noticed that especially younger members often used similar phrases to those written on the HUB website. A young member said, for instance: "if you have an idea but don't really know what to do, it is a great place to be because there are a million things going on" (Kate), and another young member who had joined recently said: "here you see collaboration, the best you do is the best you can bring to society" (Anna), while on the HUB website it is written that if "you have the first sparks of an innovative idea... the HUB provides a carefully curated experience to help" ('The HUB: Experience', 2013), and that the aim is to "enable collaborative ventures for a better world" ('The HUB: About', 2013).

Another way interviewees might have been biased is through knowledge in the social sciences. Most interviewees were highly educated and some had studied or were teaching or doing research in the social sciences. Theories they knew might have shaped their answers; they might have presented a theory as their own answer or their answers might have been influenced by the fact that they knew what theories I could apply to their answers. Such double hermeneutics became visible when interviewees referred to theories they had read or when they recommended literature to me (Giddens, 1991). This happened often during interviews; interviewees said, for instance, "there is this whole idea, you might have come across it in sociology, Martin Buber, the fact that interaction makes communication better" (Robert), or "I truly believe and I am sure I have been told somewhere online, the processes of talking ... are connected somehow to the actual ... understanding part of your brain" (Joanne). Some interviewees also recommended theories to me after the interviews (Timothy, Thomas) or sent me articles by email (Nathalie, Robert, Louise). In order to decrease the interviewees' biases I stressed that my research was independent from the HUB management and I avoided telling them much about my research.

3.6. SELECTION BIAS

Lastly, the research could be seen as running the risk of a selection bias of the setting as the HUB members were members precisely because they valued the physical co-presence of other people (Neuman, 2011). Interviewees also said that the HUB was not suitable for everyone, but rather for a particular type of person (Thomas, Michael). Because I only interviewed certain types of people, one could question the general applicability of the research and recognise the potential risk of committing a fallacy of reductionism or population generalisation (Neuman, 2011). The method of selecting interviewees could also be seen as carrying a risk of selection bias. Since I interviewed mostly people who started a conversation with me, I might have unintentionally selected more communicative members. These are of course relevant points, but I want to emphasise that I did not choose the HUB as a setting to find out what the general population was thinking about physical space, but rather because I saw the HUB as representing a new and recent model of valuing physical space that I thought would be interesting to investigate.

The Hub Kings Cross: Downstairs (Cranston, 2011)

4. DATA AND ANALYSIS

The interviews showed that sharing a physical space at the HUB positively influenced productivity, energy, and trust. In this section, I will apply the theory outlined above to the observations and interviews at the HUB.

4.1 PRODUCTIVITY

The first effect of physical co-presence that many interviewees at the HUB mentioned was an increase in perceived productivity. Goffman's (1959) theory about the influence of the presence of others on an individual's behaviour can be used to understand this finding. One can argue that because people were surrounded by other people at the HUB, they acted out a certain role that helped them to be more productive. However, Goffman's distinction between front and back stage seemed to be less clear at the HUB.

4.1.1 ROLE PLAYING

To start with Goffman's (1959) idea of role playing, one could say that people at the HUB took on a 'HUB role' which helped them to be productive. By signing up for a membership and using the space, one could argue that members take on the "collective representation" of the HUB, an already established front—appearance and manner—that they do not create but select (24).

Although clients that come to the HUB could be seen as an audience for a HUB team performance of being professional, I want to focus on individual performances of being productive in front of other people at the HUB as the audience. From observations and interviews, I would describe the 'HUB role' as being sociable and productive. The HUB was often described as a setting that was between formal and informal (Joanne, Emma) and one interviewee stressed how in a formal setting people "want to project the image of a completely competent, capable person" and in an informal setting they want to show that they "are easy to engage" (Joanne). Many interviewees also described people at the HUB as sociable or social (Nathalie, Michael, Jennifer, Timothy, Thomas, Emma), and as motivated to work (Christopher, Robert, Jennifer, Emma). As for appearance, people at the HUB mostly wore casual clothing, but nothing that would be considered inappropriate. In terms of manner and control of standards, such as matters of politeness and instrumental and moral requirements, they seemed to adhere to certain underlying rules of how to behave around other people. One interviewee complained, for example, about another member being extremely loud, but he thought it would be "inappropriate" to tell him (Timothy). Other expressions of manner were that people said they respected other people who were working (Anna, Peter, George) and accepted "other people's privacy" (George). They also said that people generally did not "interrupt" or "distract" other people because they did not "want to be rude" (Timothy) or did not want to "come across as a chit chatty person" (George). Apart from control of standards, people at the HUB also seemed to have control of the setting. In a way they hired the HUB for a special performance (20), and the space was designed to be sociable and productive, having communicative and more work-focused areas. Thus, one could say that the HUB members took on a pre-established 'HUB role' that encouraged them to be productive.

In terms of Goffman's theory, it can be argued that the 'HUB role' was internalised in three different ways. Firstly, the 'HUB role' was learned by copying existing fronts from other members (24). Interviewees said that they were encouraged to be productive through measuring themselves against other people in two ways. On the one hand, being with productive people made some people feel bad about not being as productive. One interviewee said for instance: "it makes me feel guilty if ... everyone is working and I don't get anything done" (Sarah), and another interviewee agreed that "seeing that productivity makes you measure how much work you have done and makes you realise: 'oh I have to do this'" (Nathalie). On the other hand, people also felt encouraged to be productive by observing the success of other people (George, Sarah, Timothy, Kate, Thomas). Interviewees said: "people making progress makes me want to progress on my project as well" (Sarah) or "when people are busy that makes us busy as well" (Thomas).[3] One interviewee reported that when he first joined he listened to other people to find out how they worked and improved the way he worked accordingly (Robert). Another interviewee also saw other people at the HUB as role models and said that seeing her role models being sometimes "disengaged or bored" would reduce some of "the stress and pressure" (Joanne). She said: "if you have these moments when you are like 'Oh, I don't wanna do it anymore' ... you see people yawn and typing away industriously and it re-inspires me because you think 'Oh they are in the same boat as me, there are maybe also bored but they are still working!'". In this sense, one could say that through measuring themselves against others, people took on the 'HUB role' that had a positive effect on their perceived productivity.

Secondly, using Goffman's theory, one could also say that the 'HUB role' was taken on subconsciously (26). People at the HUB often reported that they felt a 'productive atmosphere' created by others that helped them to work better.[4] One interviewee perceived the atmosphere as "entrepreneurial" and observed how this had made him become more entrepreneurial: "That's the kind of place where people want to do something and then they do. So I think that there are elements that rub off on me." (Robert). Also, one interviewee who was just visiting the HUB said that she felt a "productive atmosphere but in social way" that made her want "to do work and be productive" (Elizabeth). Another interviewee expressed the rather subconscious encouragement by other people with the words: "the productivity is held by the people who are around you" (Emma). Such subconscious encouragement to be productive can also be understood in terms of Collins' theory about co-present interaction rituals that produce emotional energy that I will elaborate on in the next section. Through Goffman's lens, the subconscious encouragement could be interpreted as a subconscious internalisation of a 'HUB role' that was beneficial for productivity.

Thirdly, the internalisation of a 'HUB role' can also be seen as reinforced because people wanted to convey a view that others found acceptable (8). Many interviewees at the HUB reported that they did not want to be seen as unproductive by other people. One interviewee compared the HUB to a gym, saying that because everyone is working very hard, it is very obvious "if you are skiving" and thus you try not to do it (Emma). Another interviewee said that if there are people "monitoring" her she thinks "I can't just sit here. ... they will see me doing it and I want to project the image that ... I am really focused and dedicated" (Joanne). Another interviewee said that there is a "slight social pressure" not to be distracted by the Internet. He said that although he himself sometimes teases people when they are on Facebook, no one would actually tell anyone else not to be on Facebook but just "the fact that other people can see you ... makes you feel your own conscience more" (Christopher). He found it embarrassing to be seen and judged by others while wasting time and described the presence of others as "a little nudge to get you to live up to your own expectations" (Christopher). Another interviewee expressed the same thought with another metaphor: "there is an instant mirror held up to you" (Elizabeth). Thus, one could argue that since people did not want to be seen as unproductive by others, they were encouraged to take on the 'HUB role' and be productive.

In this sense, one could say that people enacted a 'HUB role' by measuring themselves against others, by a productive atmosphere, and because they did not want to be seen as unproductive and that this role increased their perceived productivity. However, it should be kept in mind that although the majority of interviewees mentioned productivity as one of the main benefits of sharing a physical space at the HUB, four interviewees did not agree (Kate, Louise, Harry, Peter) and people also said that working at the HUB was only beneficial for a particular type of person (Thomas, Michael). Furthermore, although many interviewees said that people were different when surrounded by other people (George, Sophia, Michael, Robert, Christopher, Joanne), some interviewees argued that people at the HUB were less actively engaged in role playing than people in other social settings (Michael, Timothy, Thomas) or that role playing was not being a "fake person" but more a natural habit of "stepping into a different mode of thinking" (Joanne).

[3] Other quotes that emphasise the point that people were encouraged to be productive by other productive people were: "it is definitely a motivator when you see other companies that are also very successful" (Timothy), "if you see people who have started their own thing and made it work, I find that very inspiring" (Kate), or "people here ... are very hard workers so that make me wanna go that bit extra" (Jennifer).

[4] Some interviewees described this atmosphere as "industrious" (Thomas, Joanne), as a "whole work environment" (Timothy), a "working mood" (Michael) or a feeling that "subconsciously" encourages you to work hard (James). Others saw it as "an atmosphere conducive to be productive in a kind of free thinking way" (Robert) or as a "booze" to be productive (Jennifer).

The HUB Kings Cross: Upstairs (Cranston, 2011)

4.1.2 BACK STAGE AND FRONT STAGE

However, the 'HUB role' was not, like Goffman claims, prepared on a backstage and enacted on a front stage but the distinction between front and back stages seemed to be much less clear at the HUB.

4.1.2.1 BACK STAGES

Goffman argues that back stages are always "necessary", that the distinction between back and front stages is "everywhere in our society" and that there are "always" problems when this distinction gets blurred (105-107). However, the fact that the HUB does not have a proper backstage speaks against the necessity of a distinction between front and backstage. The HUB is an "open plan office" and it is basically just one multi-layered room (Nathalie); wherever people are in the building they can be seen by other people. However, the lack of distinction between front and back stage is not seen as a problem by the members. Although some interviewees said that it would be useful to have a bit more private space for phone calls (Timothy, Emma), most people did not seem to mind the lack of privacy in the building (Michael, Nathalie, Jennifer, Kate, George). Their responses, when asked if they felt restricted by the space, were actually very positive, such as: "No, no, I don't really need my privacy!" (Michael) or "I don't feel restricted at all!" (Jennifer). In this sense, the HUB speaks against Goffman's claim that back stages are always crucial for performances.

4.1.2.2 USING SUB-SPACES

For Goffman, the only way that the distinction between front and back stages can get blurry is when parts of a front stage are turned into a backstage by invoking a backstage style (112). Although people at the HUB seemed to use different parts of the building for different purposes, I would see that as creating sub-spaces rather than back stages on a front stage. At first, everything at the HUB seemed like one 'big space' to me, but after a while I identified different sub-spaces: the most communicative area was around the information desk and café downstairs. People ordered food or drinks or went behind the counter and prepared their own food or beverages. They also often went to this area intentionally to find someone to talk to (Jennifer, Christopher) and often said 'hi' or introduced themselves to others. It was the loudest and most informal area, people sang, laughed, or made fun of and with each other.

Next to the café was one of the two working areas with about ten round tables that was quite loud and interactive.[5] Most interviewees only used this area to talk to people, for lunch or for meeting guests (Sarah, Thomas, Michael, Emma, Christopher, George, Louise). Other interviewees worked downstairs regularly out of convenience (James) or because they had to make many phone calls (Timothy, Jennifer). Upstairs was the more quiet working area that an interviewee described as having a "completely different vibe" compared to downstairs (Lucy). There were different kinds of tables and a few tables were reserved for 'anchor teams'. People also talked, but more quietly than downstairs. Many interviewees said that they preferred working upstairs because they could concentrate better (Sarah, Thomas, Michael, Emma, Christopher, George).

When people needed more private space they could rent one of the three meeting rooms on the first floor. The rooms could be closed, but doors and windows were made of glass, so that inside the meeting rooms one could be seen by people on all other floors. Often, even the content of the meetings was visible to others because people wrote schemes and notes on the glass windows.

Furthermore, there were four seemingly private corners in the building. The two corners downstairs with one or two armchairs were visible to everyone in the room but a bit separate, and people often went to these areas to make calls or to work without a computer. The private area on the first floor was just in front of a meeting room but perhaps the quietest area. The corner on the second floor was the most relaxing area, composed of two armchairs and two beanbags. Although still visible to everyone on that floor, people went to this area to relax, to lie down, to read, or even to sleep. One person I met there said: "It is always a good escape up here!" (Field Notes, 3).

The description of different sub-spaces in the HUB building has shown that different parts had different purposes and meanings for members; however, I would not describe the more private sub-spaces as back stages on a front stage. I did not observe any 'backstage behaviour' in the 'backstage-like' areas such as "smoking, rough informal dress, minor physical self-involvements, shouting ... humming" (Goffman, 1959, 111). Rather in contradiction, I observed more 'back stage-like' behaviour in more 'front stage-like' areas, such as the café and downstairs working area. In these areas people were, for instance, humming, calling each by their first names, laughing, joking, or speaking their native language. Thus, although I saw sub-spaces at the HUB, I could not observe back stages in the Goffmanian sense.

4.1.2.3 INDIVIDUALISING SUB-SPACES

According to Goffman, parts of a front stage can also be turned into a back stage by "acting in a familiar fashion" (112). The HUB members found their own sitting spots and individualised them. But again, I would understand that as individualising sub-spaces rather than as creating back stages. Interviews and observations showed that people tended to sit in similar areas and that there were different groups sitting together (Emma, Robert, Kate, Christopher). The community manager observed, for example, that upstairs "the regular people tend to sit at the long table" in the back and that "casual members find it intimidating to sit at that table" (Nathalie).

One interviewee, usually sitting upstairs in the front, confirmed this statement, saying that if he sat in the back now he would be the "new guy" and feel "outside to the others", similarly to when he first joined (Christopher). Another interviewee who was always sitting downstairs said that if he went upstairs now, he would feel different and think: "oh, I am upstairs" (Peter). When asked why they sat at the same spot, people said that it was "out of habit" (Christopher), that it made them feel more "comfortable" (Kate, Christopher), or that it felt like their "own space" (Kate, Anna).

People individualised their sitting spots by bringing objects with them, such as a little piano, several laptops, keyboards, scanners, folders, lamps etc. (Field Notes). Interviewees said that the fact that they could bring their own food and equipment created the "right amount of comfort" (Emma, Joanne) that made it "home-like" without "all the associations of home" (Joanne). To reinforce the feeling of an individual space, people also often used symbols that created boundaries, such as an open laptop or ear phones to show that they did not want to be disturbed in their own space (Michael, Christopher; Field Notes). Even without ear phones, people sometimes seemed to be in their 'own little world' and blocked out what was happening around them. One interviewee claimed that "people don't listen" and gave the example that people who were sitting next to her while she was talking about her wedding were very surprised that she was getting married when she talked to them afterwards (Nathalie). Because people seemed to find their 'personal space' in the open building, one interviewee said: "there are no boundaries in that space but they get created by people" (Christopher).

However, again the finding that people individualised their favourite sitting spots suggests that they created sub-spaces rather than back stages. In their individualised spaces, people did not behave in a particularly 'back stage-like' way. On the contrary, when mostly 'cordoned up' in their sub-spaces, people were usually mostly engaged in enacting the productive 'HUB role'. Therefore, I would suggest that there was no back stage in the Goffmanian sense at the HUB.

To conclude, this section has used Goffman's theory to understand the perceived positive effect of physical co-presence on productivity at the HUB. The enactment of the productive 'HUB role' can be seen as beneficial for productivity. However, Goffman's clear distinction between front and back stage has been relativized at the HUB. More generally, since open plan working spaces have become predominant (Bradley, 2003), what Goffman wrote more than 50 years ago needs to

[5] Some interviewees described this area as "busy" (Michael), "crowded and noisy" (Thomas), "exhausting" (Michael), and "distracting" (Michael, Sarah).

be rethought in today's time. In terms of productivity, maybe it is precisely an 'in-between level' of front and back stage that is beneficial, since it makes people feel comfortable, as if on a backs tage, while at the same time making them feel obliged to live up to the expectations of others, like on a front stage.

The HUB Kings Cross: Upstairs Corner (Cranston, 2013)

4.2 EMOTIONAL ENERGY

The second factor why many interviewees at the HUB valued sharing a physical space with others was that they felt an increased level of energy. This finding can be analysed through the lens of Collins' (2004) theory about how physical co-presence encourages interaction rituals that create emotional energy.

4.2.1 REQUIREMENTS FOR INTERACTION RITUALS

Collins proposes four requirements for an interaction ritual to take place, which can be seen as having been met at the HUB. First, people at the HUB were physically co-present, sharing the same open space. In this space, people were able to affect each other indirectly and directly with their bodily co-presence. Indirectly, interviewees reported that the mere presence of other bodies in the room had different effects, for instance on productivity, as shown in the previous section. Also, the background noise and action that bodies produced were seen as having an impact on people. Some interviewees reported, for instance, that bodily noise helped them to maintain concentration (Jennifer, Lucy, Joanne, Louise) or that "spontaneous happenings", such as someone dropping a mug and everyone reacting to it (Lucy), accidently kicking someone under the table, or smelling a nice soup (Joanne), made them feel more lively and awake (Lucy, Joanne). Bodily co-presence at the HUB could also directly affect people when they were interacting with others, asking for help, or networking.[6] More generally, people seemed to agree with Collins that physical co-presence was important for human beings.

Interviewees stressed that humans were "social animals" or "social beings" (Thomas, Joanne, Peter) that were "meant to be operating in social context" (George), and that interactions in person were more "natural" (Thomas) and "just more human" (George).[7] The second requirement for an interaction ritual, namely boundaries to outsiders, was also met at the HUB to a certain extent. Members had to sign up, to pay a monthly fee and then they got a card with their name to enter the building. Outsiders were only allowed in if they were guests of members or potential new members. They had to ring the bell, explain themselves, and sign up at the reception desk. Guests were only allowed to stay for a limited amount of hours and potential new members normally just got a short guided tour and left soon after. 'Outsiders' could thus only have limited and controlled access to the HUB; as one interviewee put it: "not everyone can just come in" (Louise). Such boundaries to outsiders encouraged interaction rituals, as reported by one interviewee who said that because people at the HUB were all members, they thought it was "okay to approach people when they wouldn't if they just met someone on the street" (Kate).

I was also able to observe Collins' third requirement for interaction rituals—a common mood—at the HUB. First of all, by signing up and going to the HUB, members already had a "common ground" (Kate). Also, people seemed to go to the HUB for common reasons, such as work and social interactions, which created a similar frame of mind. A common mood can also be seen as reinforced because of similarities among HUB members. Many interviewees identified similarities between the people at the HUB in terms of working attitude and personality: people were described as self-motivated professionals[8] and independent and sociable people with shared values[9].

Lastly, it can also be argued that Collins' requirement of a mutual focus of attention was realised at the HUB. When people interacted, they paid attention to the same objects, people, or words. They were doing similar things at the HUB, such as working, having breaks, buying or warming up food, having lunch, having coffee, talking to each other etc., which can be seen as reinforcing a mutual focus of attention. Also, the similarities among members were sometimes seen as improving mutual attention. Interviewees reported that they liked it at the HUB that people "were doing the same thing" (Joanne, Sarah) because that created a "more comforting feeling" (Sophia, Elizabeth) and made it easier "to relate to them" because people were in a similar "emotional state" (Joanne). Therefore, one could say that the HUB fulfilled Collins' requirements for interaction rituals—bodily co-presence, boundaries to outsiders, common mood and shared focus of attention.

4.2.2 INTERACTION RITUALS

I was also able to observe a few interaction rituals at the HUB. The main interaction ritual was the conversation, which is also the most common interaction ritual according to Collins. Especially in the café area and when people were sitting next to each other, I observed recurring conversation patterns that would confirm Collins' analysis of a conversational ritual. When people did not know each other, they often introduced each other, or sometimes a third person, often a member host, introduced them. The first question that followed an introduction after "nice to meet you" was often "what are you doing?" (Field Notes, 1). People exchanged basic information and expressed interest in the other person through asking more detailed questions or showing agreement, saying for instance "Oh cool" or "great!" (ibid.). If people already knew each other, the conversation would often evolve around neutral questions, such as "how was your weekend?", "how is it going with your project?" or around specific questions that showed that an earlier conversation had taken place before (ibid.). Conversations seemed highly coordinated and

[6] Many interviewees reported that other people had helped them with their work (Sarah, Lucy, Timothy). Examples of this were help with legal forms and web domains (Sarah), help with PR (Timothy, Jennifer), or help with resources (Robert) or ideas (Thomas, Sarah, George, Christopher, Anna). Some interviewees had even worked for someone they had met at the HUB (Emma, Kate, Nathalie, Louise, Peter).

[7] Interviewees also said: "we are made for meeting in person ... it is just like that" (Thomas), or "people need people" (Lucy). Others claimed that "spaces are physical" because "we are rooted in our biology" (Harry), "everyone needs human interactions" (Peter) and "everyone prefers to meet with people in person" (Sophia, Nathalie).

[8] Interviewees said that people worked for public welfare (Robert), had "start-ups" (Nathalie, Jennifer), were "self-employed" (Thomas) and "would find it depressing to work in a big company" (Christopher). They described people as "self-motivated" (Christopher), as "hard workers" enjoying their work(Jennifer), as having "passion behind what they are doing" (Christopher), and as "working ... operating ... thinking the same way" (Joanne).

[9] People at the HUB were also described as "independent", "individualistic" (Thomas), and "interesting" (Christopher), as "inspiring"(Jennifer), "quite intelligent" (Robert) as about the same age (Robert), and as "creative" (Jennifer, Christopher). They were seen as being "sociable" (Nathalie), "social" (Michael, Jennifer, Timothy), "jolly" (Jennifer), as having an "intrinsic need to mix with other people" (Thomas), and as being "curious about what you do" (Emma). Interviewees also described people as having shared values (Robert, Lucy, Michael), such as wanting "to change the world" (Michael).

transitions from one topic to the next seemed to run very smoothly. Also, voices were altered according to the context of the conversation. For example, in the first week people always said "Merry Christmas" and "Happy New Year" with a high pitch, and when the heating system did not work, people kept saying: "It is so cold" with an emphasis on the word 'so' (2). Laughter was also often produced in conversations; people made jokes quite often, even with people they did not know well. Also in line with Collins' model, conversations were accompanied by bodily movements. People used bodily movements to stress their points through hand movements or pointing to something on paper or on screen. They also used touch. For example, two people working together did a 'high-five' after a phone call, a girl hugged another girl because she was feeling cold, or two people made fun of each other and pushed each other in a joking way (2). One interviewee also reported that "physical contact is very important" for him and that he liked to "tickle" people at the HUB, "pet their hair" or have "little fist fights" with them (Michael). Although some conversations were probably more about the content—especially work-related ones—I would agree with Collins that many conversations were not only formally but also substantially ritualistic in the sense that they were more about the 'feeling' than about the content. Many interviewees also reported that small talk helped them to work (Sarah), to "refresh your mind" (Lucy), to "clear your head" (Timothy), or to "switch off for a few seconds" (Michael, Anna).

Apart from conversations, I also observed some more small-scale interaction rituals, such as having coffee or cigarettes together or going out with the same person to buy the same lunch several times (Field Notes). When saying 'hi' or 'bye', people also often followed certain ritualistic patterns; they hugged, shook hands, or waved and smiled. Smiling could almost be seen as a small ritual in itself. People often smiled when entering and leaving, when meeting or passing by someone, when their eyes met the eyes of someone else, or when they had a conversation (1). Another set of interaction rituals took place as reaction to what was happening in the space. For example, someone dropped something and someone else picked it up, someone tripped over a cable and people offered help, or a table was unstable and people fixed it together (ibid.). Members also often shared food with people sitting at the same table or asked if they could get them a drink when they got one for themselves (ibid.). To conclude, while conversation was the main interaction ritual that I observed at the HUB, there were a few more interactions that would fit Collins' model.

4.2.3 OUTCOMES OF INTERACTION RITUALS

Collins identifies four outcomes of interaction rituals that I was also able to observe at the HUB. Maybe the most important outcome is the creation of emotional energy that leads to initiative to action, confidence, strength and enthusiasm. Although interviewees did not use the term emotional energy, many interviewees reported that sharing a physical space helped them emotionally (Michael, Joanne, Elizabeth, Sophia) and with their energy levels (James, Emma, Christopher, George, Joanne). Sometimes, energy was even one of the main reasons for going to the HUB (James, Emma, Christopher), and people expressed their personal need for it, saying for instance: "I am very much an energy person" (James). Interviewees saw other people as a reason for experiencing increased energy, describing energy as a feeling you get from other people who make you pressure (Nathalie) or as a state you reach "by speaking to other people" (Harry). Interviewees felt energised from people "working for a similar goal" (James) or from going through a "full body, sensory experience" due to other people (Elizabeth). One interviewee also reported that while in a normal office there was often a "down energy", there was an "up energy" at the HUB (Christopher).

Another interviewee showed how she was energised by other people by using a metaphor, comparing her brain with a car engine: "the stuff that I read is the fuel going in, but I need to interact with people, to talk to people, look at people. That gives the spark that keeps the engine busting ... otherwise I stagnate" (Joanne). Because of this "burst" she got from social interactions, she said that she had "tried just having TV on in the background" when writing her master thesis, but that this did not have the same effect. In terms of Collins' first characteristic of emotional energy, namely initiative to action, emotional energy can be seen as a factor explaining the findings of increased productivity analysed in the previous section. As for confidence and strength, one interviewee said that he felt more confident in approaching people he did not know since joining the HUB (Robert) and another interviewee reported how being at the HUB helped him to get into a "mood" that made it easier to do things which he was not used to doing (Harry). Also, people often reported that joining the HUB had had a positive effect on their "well-being" (Peter, Robert). Interviewees stressed that being with other people positively influenced their "mood" (Christopher), "happiness" (Jennifer, Kate), or made them feel more "alive" (Anna), "awake" (Elizabeth, Joanne), and "safe" (Joanne, Louise). In terms of enthusiasm, one interviewee talked about how enthusiasm about a project was easier to build up in person or on the phone than online: "you do bounce off each other ... this energy ... the shared enthusiasm" (Christopher). Another interviewee also described face-to-face interactions as making her feel more "excited" and "enthusiastic" (Joanne).

Apart from emotional energy, a second consequence of a successful interaction ritual, according to Collins, is the production of symbols of membership, such as icons, words, a third person, gestures, first naming, or jargon. At the HUB, an obvious symbol of group membership was the membership card that allowed people to enter the building. The quite frequent exchange of business cards, Linkedin details or email addresses could also be seen as symbols of group membership (Field Notes). Furthermore, one could also say that symbols of membership were produced in conversations. As shown before, people tended to ask more specific questions if they had talked to a person before, such as, for instance, "how is your eye doing?" or "how are your wedding preparations going?" (1). By doing so, they showed that a previous interaction had established a bond between members. Also, people referred to third persons with words and gestures, telling what someone was doing or pointing to other people. Gestures, such as waving, 'high-fives', or touching, can also be understood as symbols of group membership. Most people also called each other by their first names, which created a more casual atmosphere and a feeling of belonging. Although I could not identify any typical 'HUB' jargon, I observed a rather similar way of speaking and interacting in a polite and sociable way. But this could, of course, also have been due to the given similarities among members.

The third outcome of a successful interaction ritual, according to Collins, is a feeling of group solidarity. Interviewees often reported that there was a community feeling at the HUB (James, Anna, Kate, Robert, Emma). Many interviewees also named being part of a community as one of the main reasons for joining the HUB (George, Anna, Kate, Robert) and one interviewee called the HUB a "micro village" in a city without a "big community feel" (Kate). Communal activities, like pub crawls or making a birthday card for a member, took place at the HUB (Field Notes). However, most people reported that they did not meet up with others from the HUB outside the building very often (Peter, Sarah, Thomas), and observations showed that not everyone was equally involved in the community.

In terms of Collins' last outcome of an interaction ritual, namely shared morality, many people stressed that members at the HUB shared the same values (Robert, Lucy, Michael. Anna, Timothy, Nathalie). A value that was, for instance, mentioned several times was that, at the HUB, there was 'collaboration instead of competition', something that was hard to find outside the HUB (Anna, Timothy, Nathalie, Robert). Maybe the feeling of shared morality was reinforced by interaction rituals, however, the community manager told me that people were 'tested' before entering the community, so that they had similar values (Nathalie). She also said that people did not always adhere to the main values of the HUB—transparency, collaboration and courage—and would, for example, sometimes hide what they were working on from other people. Therefore, outcomes of interaction rituals—emotional energy, symbols of group membership, solidarity, and shared morality—could be observed at the HUB, but it was not always clear whether those outcomes were caused by interaction rituals.

Applying Collins' model of interaction rituals to the HUB has shown that the requirements for interaction rituals seemed to be met, that interaction rituals took place and that outcomes, especially emotional energy, could be observed. The analysis of interaction rituals at the HUB can help to explain the finding that people sought physical co-presence because it increased their energy level. It also stresses the importance of physical co-presence, since physical co-presence is an essential requirement for interaction rituals.

4. 3 TRUST

The last one of the three main reasons why interviewees valued physical co-presence at the HUB was that they could trust people more easily in person,

because of a shared common ground and improved communication, understanding, and relationships. In this section, I will apply scholarly literature about trust and physical proximity to those findings at the HUB.

4.3.1 COMMON GROUND

Scholars have argued that common ground contributes to the establishment of trust and that developing common ground is easier in a physical space because people hear, see, and experience the same things (Fussel et al., 2012), can exchange objects (Rocco, 2005), and can create new similarities (Möllerig, 2005). I was able to observe those factors at the HUB. In terms of hearing the same things, background noise sometimes had an effect on people and it was often a topic of conversations. For example, during an interview, the coffee machine was suddenly very loud, and we both started laughing and commenting on it, which made the interviewee a bit more relaxed afterwards (Lucy). Conversations would also often evolve around things that were visible; when hosts wrote the event schedule on a wall, people started talking about it, and people started conversations with me, saying: "I really like your jumper" (Joanne in Field Notes,1) or "that looks like a wholesome drink" (George in Field Notes, 1).

Because people shared the same place, they also shared experiences. For example, when the heating system was not working people shared the same experience of feeling cold and annoyed. Also, all living in London, they experienced similar feelings when there was a helicopter crash in London, or when it was snowing outside and the underground line did not work properly. Although people worked on different things they still had the shared experience of working and, as shown before, the people at the HUB were quite similar in many ways, which can be seen as contributing to the feeling of sharing common ground. In terms of objects, people shared tables, kitchen equipment, food, chargers, pens, the printer and so on with each other, which can be seen as strengthening common ground. One can also argue that new similarities were created through conversations and rituals as shown in the previous section.

Some interviewees observed a relationship between common ground, through a shared physical space, and trust. One interviewee said: "you are in the same space, so you are connected physically, but also mentally", and he stressed the importance of such connections to establish trust (Michael). The community manager also said that, at the HUB, there was "an automatic trust", because members had all been interviewed to assure that they had similar values (Nathalie). Therefore, the findings suggest that, through physical co-presence at the HUB, people were able to develop common ground that helped them to build up trust.

4.3.2 COMMUNICATION

Secondly, studies have shown that physical co-presence encourages trust because it improves communication which has a positive impact on trust (see for example Bijlsma-Frankema & Woolthuis, 2005). Fussel et al. (2002) and Urry (2005) both argue that physical co-presence makes communication easier because it helps to give feedback and involves non-verbal interactions. Many interviewees mentioned similar factors. As for feedback, one interviewee said that it was easier to postpone a deadline online because you do not get "instant feedback" (Nathalie). Other interviewees said that they liked to get "instant feedback" on their work from other people at the HUB (Thomas), or that, in physical co-presence, you could get "the more subtle feedback" (Christopher).

Furthermore, many interviewees also saw non-verbal interactions as an essential factor in improving communication in a shared physical space. They said that physical interactions allowed a more "rounded form of communication" (Robert) because they made it possible to get the "subtleness of communication" (Emma), to read "cues of communication" (Harry), and to observe "people's mannerisms" (Christopher). Interviewees mentioned many examples for non-verbal interactions, such as eye contact (Anna, Elizabeth, Joanne, George), moods, reading and reaction to expressions (Anna, Christopher, Emma), voice intonations (Anna, Elizabeth, Christopher), body language (Elizabeth, Christopher, Robert, Joanne, Jennifer), looks (Christopher), sounds (Elizabeth), laughter (Robert, Christopher), or gestures (George, Joanne), such as doing "cheers" (Thomas) or shaking hands (James). Non-verbal interactions were also an important factor for interviewees preferring physical over virtual spaces. Compared to online communication, interviewees often reported that non-verbal interactions made a conversation more profound[10], more interesting[11], and more emotional and pleasant[12]. The preference for offline over online communication was also stressed by the fact that most people did not use the HUB's online network facilities (Sarah, James, Thomas, Timothy, George, Anna, Harry, Emma, Robert, Peter).

Some interviewees also said explicitly that non-verbal communication made it easier to establish trust (Michael, Robert). Hence, people saw a link between physical co-presence and communication and trust.

4.3.3 UNDERSTANDING AND JUDGEMENTS

The third reason why physical co-presence has a positive impact on trust identified by the literature is that it fosters understanding and judgments which in turn help to establish trust (Urry, 2003; Rocco, 2005; Bijlsma-Frankema & Woolthuis, 2005). This also explains inconvenient travel, for instance, in business (Urry, 2003). Interviewees also often stressed that physical co-presence made it easier to understand and judge someone (Timothy, Christopher, Elizabeth, Sophia, Joanne). Many interviewees had worked or were working with people from other parts of the world but they said that they often travelled to see their clients in order to better understand them (Timothy, Harry, Christopher). One interviewee said that he always felt the pressure to get on a plane to see his clients which helped him to clarify things because then he could feel "what the other wants ... [him] to do" (Harry). The community manager also reported that she asks connection members that are only part of the online HUB network but do not use the space "to come in for a coffee", because that would help her to "understand" them and to find out how to "support them" (Nathalie). One interviewee who had worked for people from different countries, realised that the only time that a project did not go well was with a client he had not met in person (Christopher). He said that in person, it is easier to "express your expectations", "to notice if there is a problem of incorrect expectations" and to "understand each other" (Christopher). One interviewee, working with a partner online, said that it is easier to understand the "whole topic" in person (Michael) and another interviewee said that there is "something that necessitates this inconvenient travel and accommodation" (Robert). People who were not working with someone online also said that they would not like it, but that, if they had to, it would be important to meet in person in order to be able to understand each other (Sophia, Elizabeth).

More than in terms of understanding, interviewees also often said that it was easier to make judgments about someone in person (Emma, Christopher, Timothy). Compared to online spaces, where people could 'make up' their personality (Emma, Harry, Robert, Sophia), people considered physical encounters more "authentic" (Robert, Michael) because they could get a better impression of people.[13]

They said that they could "pick up on [people's] energy and vibe much more easily" (Joanne) and look through the "role of being professional" (Christopher).

[10] Face-to-face conversations were seen as producing "a higher quality of conversation" (George), "deeper responses" (Nathalie, Robert, Harry), and as allowing more variety, complexity and complication (Kate, Nathalie, Sarah, Thomas, Joanne). Communication in person was described as "easier" (Sarah, Thomas, Emma), "quicker" (Harry, Kate, Emma, Louise), more "efficient" (Michael, Emma), more "productive" (Michael, George), more collaborative (George, Louise) and as better for improvisation (Louise).

[11] Interviewees described communication in person as "interesting" and "engaging" (Joanne), "stimulating" (Robert), "inspiring and motivating" (Elizabeth), as impactful (Elizabeth, Nathalie), as involving more senses (Sophia, Elizabeth), as connecting (Harry) and changing people (Elizabeth) and as being more of an "experience" (Elizabeth).

[12] Face-to-face communication was also described as less "dry" (Michael, Christopher) , less "cold" (James) and more "personal" (George, Anna, Lucy, Kate), more "emotional" (Sophia, Christopher, Joanne), as more "vital" (Harry), "friendlier" (Kate), "more comfortable" (Louise), "more fun" (Robert, Thomas) , "more pleasant" (George), "better for well-being" (Emma), and as "more real" (Elizabeth, Harry, Joanne), more "fulfilling" (Robert), and more "satisfying" (Joanne) than online communication.

[13] They said that in physical co-presence, it was easier to get an "impression" (Emma) or "picture"(Thomas, George) of someone, "see who they really are" (Lucy, Christopher), "get to know people's personality" (Kate, Robert), or to get "a sense of a person" (George).

One interviewee said: "if you are in a physical space, you are in a community with complete human beings; when you are in a virtual community, you are in a community with all those weird one-dimensional slices of people." (Christopher). He also said that judgments you make physically are "maybe not totally reliable" because you make a "judgment based on something other than the actual work itself". However, he still thought that making those judgments was "natural" and "probably right more often than it is wrong". Interestingly, one interviewee said that if cultural differences were very dominant, he preferred online communication, because this would make it easier to ignore "cultural patterns" that could lead to negative judgments (Thomas). He gave the example of his colleague in Pakistan who sometimes "goes for a brief prayer" during online meetings. The interviewee said that he was "completely fine" with that, while he would find it "weird" if he shared a physical space with his colleague.

Some interviewees recognised a direct link between understanding, judging, and trusting someone, arguing that, in person, you could understand more easily "if you can trust" someone (Louise, Robert, George, Joanne). In physical co-presence, you could see whether "this kind of person somehow clicks", and thus you could trust them "rather subconsciously" (Joanne). The link between understanding and trust was also often seen as a reason to travel in business. One interviewee said that trust was one reason why he travelled to see and understand his clients (Christopher). Another interviewee, working in property letting, gave the example that he had lost money when he had only communicated with landlords via phone and email, because there had been "a lack of trust" (Timothy). Therefore, he decided to meet the landlords in person to "identify their needs" and to feel "connected". Another interviewee reported that it helped him to meet up in person and do sports together with someone he needed to trust, such as a potential business partner, because that would help him to "see the real character" and establish trust: "the human behind the curtain is quite important. I need to trust people" (Michael). Thus, physical proximity was said to improve understanding, which was seen as having a positive effect on trust.

4.3.4 RELATIONSHIPS

Lastly, scholarly literature has shown that physical co-presence encourages building up trust because it helps to build up personal relationships, which are a good basis for trust (Urry, 2003; Bijlsma-Frankema & Woolthuis, 2005). Factors that improve relationships are again shared experience, non-verbal interactions, but also mutual attention and increased commitment because of risks involved in physical interactions (Urry, 2003; Klemmer et al., 2006). Interviewees at the HUB also often said that it was easier to build up a relationship with someone in person (Thomas, Louise, Sophia, Christopher, George, Luca, Lucy, Timothy, Jennifer, Elizabeth) and stressed the importance of building up a relationship in business (Christopher, Peter, Timothy, Jennifer, Emma, Christopher, Timothy, Louise). They said that face-to-face interactions made it easier to establish a connection with someone.[14] The community manager explained, for instance, that she had the best relationships with members who used the space most frequently rather than with online connection members (Nathalie). Shared experience was also seen as a reason for better relationships with a person, as illustrated by one interviewee saying that being in a physical space "moves your friendship ... forward" because you can share new experiences, even if it is "just the weather or something funny" (Sophia).

Other interviewees also mentioned non-verbal interactions as a reason for improved relationships in physical proximity (James, Joanne). One interviewee said, for instance, that when you share a physical space, you build up an "emotional connection" subconsciously, in the sense that "bodies respond to each other without you even having to register it" (Joanne). Another interviewee said that just looking at people's eyes created a more "emotional attachment" (Elizabeth). The commitment to travel for meeting up in person was also seen as helping to establish a relationship (Timothy). Interviewees reported that seeing someone face-to-face made them more committed to the relationship; in person, it was harder to "miss a deadline" (Harry, Nathalie) and people felt more "accountable" (Robert).

[14] They said that in physical co-presence it would be easier to make a "connection" (James, Timothy, Nathalie, Sarah), to "click with someone", to "tie bonds", to feel a "good chemistry" between people (George), and to "relate to", "identify with", or "empathise with" someone (Elizabeth).

Again interviewees saw a link between relationships and trust, saying for instance: "trust is connecting to people" (Joanne). One interviewee said that, because there is always a risk of being killed in face-to-face interactions, "you invest more" and build up a relationship more easily, which leads to "more solid and sustainable" trust (Thomas). Another interviewee said that, in order to advance a relationship, and to be "friendlier", people automatically have to open up, which helps to build up trust (Christopher). Altogether, establishing a personal relationship was seen as easier in a physical space and as useful for developing trust.

To sum up the analysis of trust in physical co-presence, I want to use the words of an interviewee that summarise the positive effect of common ground, communication, understanding, and relationships in physical co-presence on trust: "looking at someone's eyes, their gestures, their behaviour, their posture can give you some hints of are they honest ... how are they feeling about it, ... spending time face-to-face helps a lot to get to know a person and establish whether you can trust this person or not" (George). On the whole, in the data and analysis section, I have applied theory to the findings at the HUB that people valued physical co-presence because it increased productivity, emotional energy, and trust.

The HUB Kings Cross: Working Together I (Cranston, 2011)

The HUB Kings Cross: Working Together II (Rost, 2013)

The HUB Kings Cross: Downstairs (Rost, 2013)

5. DISCUSSION AND CONCLUSION

At the HUB, one can see people working on innovative business ideas in "a contemporary environment" ('The HUB Kings Cross: Space', 2013). They use laptops, Skype, talk on mobile phones, and network on HUB Net and Linkedin. They are modern people, using modern communication technology and still, they value the "old-fashioned" (Harry), "old school" (James) way of communicating. They "sign up to pay 300 to 400 pounds to come down to the HUB, just to enjoy the atmosphere, to be with other people" (Thomas). Interviewees at the HUB reported that being surrounded by other people helped them to be productive, to feel energy and solidarity and to be able to build up relationships and trust. Many of them, having worked at home before, also said that they had joined the HUB to feel less lonely or alone[15] (Robert, Joanne, Emma, Christopher, George, Peter, Sarah, Anna).

The HUB could be seen as part of a more general trend of valuing physical co-presence. Interviewees

[15] They described working at home as "awful" (Robert), "challenging" (Sarah), "tensed if not unsafe" (Joanne), not "healthy" or "not sustainable" (George). The lack of social interactions when working at home made them "go a little bit crazy" (Peter), "wonder if you are still able to communicate" (Robert) or loose connection to reality (Joanne).

often predicted an increasing realisation of the importance of physical co-presence in the future[16] and more and more HUBs and other co-working spaces are opening worldwide. Pohler (2012) argues that co-working spaces have emerged recently in different countries at the same time as an answer to changes in the working world towards more flexibility and subjectivity that led to increased social and spatial isolation. This trend towards seeking physical co-presence seems to counter arguments of decreased importance of local physical space brought forwards by different scholars (Giddens, 1991; Kearney, 1995; Castells, 2000; Caldwell & Lozada, 2007). Maybe the early observers of the modern virtual age were too radical in their predictions of the death of distance (Castells, 2000) or the emptying of space (Giddens, 1991).

For some people such a persisting need for physical co-presence in today's modern time could be understood from a biological perspective. As seen before, it has been argued that humans are "neurologically wired" to respond to each other in bodily co-presence (Turner, 2002; Collins, 2004) and that we build up cognitive networks through physical interactions (Klemmer et al., 2006). Our biology is seen as having evolved throughout a long period of time, whereas "technology itself has evolved exponentially in just a few decades" (Woodworth, 2011, 3). This suggests that cognitive networks evolve in slower fashion than technology, that our biology still mainly relies on interactions in physical co-presence.

More than that, one could even say that forces of modernity do not decrease but increase the need for physical co-presence. In a world where the juggernaut of modernity is seen as disembedding individuals (Giddens, 1991), and where modern rationality and bureaucracy are said to have disenchanting and dehumanising effects, building an iron cage (Weber, 2009), it is especially important to connect with people physically. Physical interactions are seen as producing emotional energy (Collins, 2004) or collective effervescence (Durkheim, 1995) and interviewees at the HUB simply described face-to-face interactions as more 'human'[17] In this sense, seeking physical co-presence could be seen as looking for more 'human connections', for a way out of a dehumanising cage of modern communication technology that reduces individuals to 'icons on a desktop' or to 'contacts in an email address book' (Weber, 2009).

We shaped the world in which we live today: a world of growing mobility and shrinking distances, a world of increasing subjective reflexivity and decreasing genuine relationships (Giddens, 1991; Simmel, 2010). With regard to physical space, we created communication technology and as objective culture it soon got a life of its own, shaping and changing us (Simmel, 2010). As Hannah Arendt (1998) said, Homo Faber, the tool maker, has created machines that transform his life (151). Technology, owing its "existence exclusively to men", nevertheless conditions its "human makers" with the same conditioning power as natural things (9). Technology is conditioning us, changing the way we think, act, and interact. But we are not victims of objective culture without agency; we are able to create new models that satisfy our needs.

The HUB can be seen as such a new way to satisfy the need for physical co-presence. Woodworth (2011) argues for a positive integration of technology that fits our physical human needs and claims that the success of future communities will depend on how well they are connected online, as well as offline. The HUB seems to fit his description of a future community that encourages online connections while providing shared physical spaces. It seems to represent a space where people try to find new ways to satisfy the need for physical co-presence in an increasingly virtual world. For further research about the current meanings of physical space, it would be interesting to do more qualitative and potentially quantitative research at the HUB Kings Cross or other HUBs. One could investigate in more depth what type of people fit this work environment, and perhaps interview people who quit the HUB. There are certainly also more reasons for seeking physical co-presence than productivity, emotional energy, and trust that would be worth investigating, such as for instance networking and understanding yourself through other people. Furthermore, research that investigates the need for physical co-presence in other settings would be very relevant. Is the idea that "spaces … need to grow" spreading and resulting "in the emergence of a global movement", as said on the HUB website? ('The HUB: About', 2013). Or are the findings at the HUB just an example of a small 'counter movement' to the mainstream movement that is going in the direction of emptying physical space? Do "we need more physical space" (Lucy)? Or do only some people need it, such as the HUB members? And in what situations is physical co-presence of particular importance? Thus, it would be interesting to research other models that integrate online and offline communication in a constructive way. Since communication technology will not disappear in the future (Woodworth, 2011), we should start thinking about possibilities to use online communication in a way that recognises a need for physical co-presence. As interviewees at the HUB said, the online world should be an "addition to the offline world, it should never be an alternative" (Thomas, Lucy, Robert, George).

[16] Interviewees said for instance: "we need more physical space" (Lucy), "this local thing is happening more and more" (Michael), "I think there should be a lot more occasions where people meet and discuss" (Robert), or "I think more and more people are going back to the old way of communicating" (George).

[17] Interviewees at the HUB saw meeting in person as "natural" (Thomas) and "just more human" (George). They said that people were social animals (Thomas, Joanne, Peter) that "are made for meeting in person" (Thomas) or for "operating in social context" (George) because "we are rooted in our biology" (Harry).

REFERENCES

Arendt, H. (1998). The human condition. (M. Canovan, Trans.). Chicago: University of Chicago Press.

Bernard, R. (2006). *Research methods in anthropology: Qualitative and quantitative approaches.* Oxford: AltaMira Press.

Bijlsma-Frankema, K. & Woolthuis, R. K. (2005). *Trust under pressure: empirical investigations of trust and trust building in uncertain circumstances.* Edgar Elgar Publishing: Cheltenham.

Blumer, H. (1954). What is wrong with social theory?. *American Sociological Review,* 18, 3-10.

Bødker, M. & Christensen, M. S. (2003). Trust in the network society, *PSU,* 1-13.

Bradley, J. C. (2003). The acoustical design of conventional open plan offices. *Canadian Acoustics,* 31 (2), 23-31.

Bulkley; N. &Van Alstyne, M. (2004). Why information should influence productivity. *Center for Business at MIT.*

Caldwell, M. L. & Lozada Junior, E. P. (2007). The fate of the local. In G. Ritzer (Eds.). *The Blackwell Companion to Globalization*. New York: Blackwell Publishing, pp. 498-515.

Cartwright, J. (2008). *Evolution and human behaviour: Darwinian perspective on human nature***.** London: Palgrave Macmillan.

Castells, M. (2000). The rise of network society. In G. Ritzer & Z. Atalay (Eds). *Reading in Globalization: Key concepts and major debates* New York: Wiley- Blackwell, pp. 245-252.

Clases, C., Bachmann, R. & Wehner, T. (2004). Studying trust in virtual organizations. *International Studies of Management and Organisation*, 33 (3), 7-27.

Collins, R. (2004). *Interaction ritual chains.* Woodstock: Princeton University Press.

Cranston, G. (2011). *The HUB Kings Cross: Downstairs* [Picture].

Cranston, G. (2011). *The HUB Kings Cross: Ground floor and first floor* [Picture].

Cranston, G. (2011). *The HUB Kings Cross: Second floor and ground floor* [Picture].

Cranston, G. (2011). *The HUB Kings Cross: Stairs* [Picture].

Cranston, G. (2011). *The HUB Kings Cross: Upstairs [Picture].*

Cranston, G. (2011). *The HUB Kings Cross: Upstairs corner* [Picture].

Cranston, G. (2011). *The HUB Kings Cross: Working Together I* [Picture].

Durkheim, E. (1995). The elementary forms of religions (K. E. Fields, Trans.). New York: The Free Press.

Fussell, S. R., Kraut, R. E., Brennan, S. E., & Siegel, J. (2002). A framework for understanding effect of proximity on collaboration: Implication for technologies to support remote collaborative work. *Human-Computer Interaction Institute*.

Geary, D.C. & Bjorklund, D.F. (2000). Evolutionary developmental psychology. *Child Development,* 71 (1), 57–65.

Giddens, A. (1991). *Modernity and self-identity.* Cambridge: Polity Press.

Glaser, B. G. (2002). Constructivist grounded theory?. *Qualitative social research Sozialforschung,* 3(3).

Glaser, B. G. & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Rutgers: New Jersey.

Goffmann, E. (1959). *The presentation of the Self in everyday life.* London: Anchor Books.

Grenier, L. (1998). *Working with indigenous knowledge: A guide for researchers*. Ottawa: International Development Research Centre.

Hermanowicz, J. C. (2002). The great interview: 25 strategies for studying people in bed. *Qualitative Sociology*, 25(4), 479-499.

Kearney, M. (1995). The local and the global: The Anthropology of globalization and transnationalism, *Annual Review of Anthropology,* 24, 547-565.

Klemmer, S.R., Hartman, B., & Takayama, L. (2006). How bodies matter: Five themes for interaction design, *DIS University Park,* 1-10.

Lee, A., Danis, C., Miller,T., & Jung, Y. (2001). Fostering social interaction in online spaces. *Human-Computer Interaction: IOS Press*, 1-8.

Möllerig, G. (2005). Rational, institutional and active trust: Just do it!?. In K. Bijlsma-Frankema & R. K. Woolthuis (Eds.). *Trust under pressure: empirical investigations of trust and trust building in uncertain circumstances.* Edgar Elgar Publishing: Cheltenham.

Neuman, W. L. (2011). *Social research methods: Qualitative and quantitative approaches.* London: Pearson.

Pettigrew, T. F. (1998). Intergroup contact theory. *Annual Review Psychology,* 49, 65-85.

Pohler, N. (2012). Neue Arbeitsräume für neue Arbeitsformen: Coworking spaces. *Österreich Zeitung Soziologie,* 37, 65–78.

Productivity. (2013, April 20). Retrieved from Princetonedu:http://wordnetweb.prince ton.edu/perl/webwn?s=productivity.

Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of Democracy,* 65-78.

Rocco, E. (2005). Trust, distance and common ground. In K. Bijlsma- Frankema & R. K. Woolthuis (Eds.). *Trust under pressure: empirical investigations of trust and trust building in uncertain circumstances.* Edgar Elgar Publishing: Cheltenham.

Rost, L. (2013). *The HUB Kings Cross: Downstairs* [Picture].

Rost, L. (2013). *The HUB Kings Cross: Upstairs corner* [Picture].

Rost, L. (2013). *The HUB Kings Cross: Working Together II* [Picture].

Rutledge, T., Linke, S. E., Olson, M. B., Francis, J., Johnson, B. D., Bittner, V., et al. (2008). Social networks and incident stroke among women with suspected myocardialischemia. *Psychosomatic Medicine*, 70(3), 282-287.

The HUB: About. (2013, May, 7). Retrieved from the HUB: http://www.the-hub.net/about

The HUB: Experience. (2013, May, 7). Retrieved from the HUB: https://www.the-hub.net/experience

The HUB Formula I (2013, May 7). Retrieved from http://kingscross.the hub.net/toolkit [Picture].

The HUB Formula II (2013, May 7). Retrieved from http://kingscross.the-hub.net/toolkit [Picture].

The HUB: Home. (2013, May, 7). Retrieved from the HUB: http://www.the-hub.net

The HUB: Inspiring Spaces. (2013, May, 7). Retrieved from the HUB: http://www.the-hub.net/experience/ spaces

The HUB: Vibrant Communities. (2013, May, 7). Retrieved from the HUB: http://www.the-hub.net/experience/community

The HUB Kings Cross: Events. (2013, May, 7). Retrieved from the HUB Kings Cross: http://kingscross.the-hub.net/events

The HUB Kings Cross: Membership. (2013, May, 7). Retrieved from the HUB Kings Cross: http://kingscross.the-hub.net/membership

The HUB Kings Cross: Space. (2013, May, 7). Retrieved from the HUB Kings Cross: http://kingscross.the-hub.net/space

Turner, J. H. (2002). *Face to face: towards a sociological theory of interpersonal behaviour.* Stanford: Stanford University Press.

Urry, J.(2003). Social networks, travel and talk. *British Journal of Sociology,* 54 (2), 155–175.

Uslaner, M. E. (2006). Does diversity drive down trust. *Fondazione Eni Enrico Thomasei Note di Lavoro: Knowledge, Technology, Human Capital*, 1-55.

Sigman, A. (2009). Well connected? The biological implications of social networking. *Biologist,* 56 (1), 14-20.

Simmel, G. (2010). The metropolis and mental life. In G. Bridge & S. Watson (Eds.). *The Blackwell City Reader*. Sussex: Wiley-Blackwell.

Weber, M. (2009). The protestant ethic and the spirit of capitalism: The Talcott
Parsons translation interpretations (R. Swedberg, Eds.). New York: Norton and Company.

Woodworth, A. C. (2011). Community and identity in contemporary physical and virtual spaces: Toward an integration. *Open Access Theses, Paper* 258.

Zvelebil, M. (1986). *Hunters in transition: Mesolithic societies of temperate Eurasia and their transition to farming.* Cambridge: Cambridge University.

APPENDICES

A1: List of Interviewees

Sarah	30-40, female, South Africa, social enterprise: de-addiction
Emma	30-40, female, UK, social enterprise: health, human rights
Michael	20-30, male, Germany, social enterprise: fashion
Louise	30-40, female, UK, fundraising/ development/ CSR/CR
Kate	20-30, female, UK, catering and events
James	30-40, male, UK, indie record label and music publisher
Anna	30-40, female, Italy, music/PR/ communication/events
Timothy	30-40, male, UK, sales and letting
Jennifer	20-30, female, UK, sales and letting
Thomas	30-40, male, Germany, restaurant and food
Christopher	40-50, male, UK, web development
Peter	20-30, male, UK, web development
Joanne	20-30, female, UK, jewellery
Harry	40-50, male, Netherlands, design and technology
George	30-40, male, Italy, leadership and organisation development
Robert	20-30, male, UK, university lecturing
Sophia	20-30, female, Germany, student
Elizabeth	20-30, female, UK, student
Lucy	20-30, female, UK, student and social business: dance
Nathalie	30-40, female, UK, community management at The HUB

(Name, estimated age, gender, country of origin, occupation)

To protect the interviewees' privacy the original names have been changed.

A2: Questions of Semi-Structured Interviews

General

- What are you doing at the HUB?
- How long have you been at the HUB for?
- Why did you join the HUB?

Physical Space at the HUB

- How is working at the HUB?
- How would you compare working at the HUB to working at home? In a library? In a café?
- Does it matter for your work what type of people you are surrounded by?
- Have you worked together with someone from the HUB? Examples?
- Have you met up with someone from the HUB outside? Examples?
- Do you use different areas of the building for different purposes?
  - Where do you normally sit?
  - Where do you normally meet people? How?
  - Do you ever feel restricted by the space?

Physical Space and Virtual Space

- How often do you use the virtual network facilities at the HUB?
  - What do you use it for?
  - Have you made a connection through HUB Net? Examples? How was it?
- How would you compare online connections to connections you made in a physical space?
- How would you normally approach another HUB member, online or in the space?
- Have you worked together with someone you only knew online? Examples?
  - How was it?
  - What was different compared to working with someone in person?
  - If not could you imagine working with someone you have only met online?
- Can you think of situations when meeting someone physically is important?
- What do you personally like and dislike about virtual and physical spaces?

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