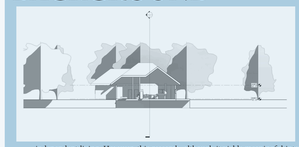
Mapping Space to Map Spatial Perception for Healthy Living

A Method of Analysis using Spatial Syntax Mapping to Improve Home Modifications for Patients with Disability

Progress Report

BACKGROUND



Negotiating the environment requires a functional relationship between multi sensory input and our brains. Our sensory systems gather information that the brain integrates and interprets as perceptions of events and objects in the world. Proper functioning of this process is crucial for safe functional performance and independent living. When the processing mechanisms from sensory input to integrated perception are affected by illness or trauma we are unable to navigate our environment safely without aids, re-training, or both. This projects studied 1) if using architecture and occupational students working together to understand home modification problems improves performance outcomes, and 2) what is the effectiveness of home modification questionnaires commonly used in occupational therapy at predicting problems of spatial configuration. **Problem**: Current research in occupational therapy focuses on numerous sub-areas of the overall problem: movement dysfunction, perceptual memory problems, functional performance, and independent living. However, this research, although it yields meaningful intervention strategies, are based on trials and errors in clinical population in health care settings. As the population with cognitive disabilities us living longer, a demand for theory and knowledge based integrated research evidence for independent and safe living at home are skyrocketing.

Innovation: We propose to develop a program for spatial analytics based on approaches in spatial syntax. Spatial syntax uses a set of techniques to break spatial arrangements into components that can be analyzed as networks of relations represented on maps and graphs to describe characteristics of those spaces [Hil96][Hil84][Hil94][Pep12][PKA+6]. Using metrics to analyze spatial configurations we hope to be able to calibrate the contextual environment to understand its affect on patients with cognitive disabilities and . It has already been shown that the way a person performs a functional task (defined as an occupational performance) is based on the way the person interprets the task-object relationship in a specified context (defined as an occupational form) [PE01]. Thus, depending on whether the form elicits meaning and purpose, the person's quality of performance and commitment to the performance will be affected. Most importantly for our study, Pedretti and Early also suggested that context affects occupational performance and that occupational therapists must understand the aspects of context (i.e., environment and objects) that will likely influence the occupational performance [PE01][Maitra07]. The most innovative aspect of the project is to combine knowledge from the architectural field and health care field using graduate students in both disciplines to optimize movement performance of a clinical population in a specific context.

Research Question

Primary Question:

What is the effectiveness of the Home Modification Questionnaire in predicting problems in the spatial configuration of home environments?

Secondary Questions:

- Does pairing Architecture and occupational Therapy students together on a home modification problem improve outcomes?
- What are the advantages/disadvantages of ARC and OT students working together on home modification problems?

Materials and Methods

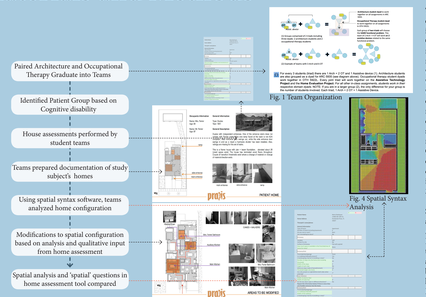


Fig. 2 (a) Documents for Existing Home Analysis, (b) Modified Home configuration

Fig. 1 Team Organization

Fig. 4 Spatial Syntax Analysis

Fig. 3 Home Assessment Tool (Chicago Home Assessment Questionnaire)

The initial study was conducted as a course offered to architecture and occupational therapy graduate students at Florida International University in Miami. Architecture students were in their 4th and 5th year of study and OT students were in a Master Seminar II. Students learned how to prepare materials for a patent application, develop a methodology for modify or re-designing existing devices, consider the context and environment in which devices used to aid human occupations operate, and present their work in the context of the health sciences. Students in architecture will work together to understand the functional needs of people with a variety of neurological and physical challenges, propose to improve upon or design new devices based on a rigorous analysis of patient needs, therapeutic outcomes and potential patent development. Architecture students were sufficiently far along in their curriculum to produce as-built drawings, model spatial relationships and present themselves professionally to a client. Groups worked together in teams of two architecture students for every five occupational therapy students. Students identified a patient group and then contacted a subject in order to make two in-home visits to 1) measure the interior home environment; 2) complete the Home Assessment Tool, and 3) interview the subject.

Students identified an older client with some sort of disability (e.g., Stroke, TBI, Alzheimer's disease, Parkinson's disease). Teams recommended a home evaluation and possible modification. Groups (2 OT student: 1 Architecture student) visited homes and evaluated the home using the Home Evaluation Checklist. Teams documented physical dimensions of the home adequate for architecture drawings, photographed, and measured any significant conditions paying particular attention to the environmental barriers unique to the client. Teams identified specific disease types and located a patient willing to allow them access to the home environment. Patient medical condition could present as chronic or acute, but the impairment to activities of daily living (ADL) needed to be persistent and significant. Students were asked to keep a journal tracking their internal team discussions.

Results

Our study was preliminary and limited by the number of students enrolled in the architecture and occupational therapy courses. The study included two semesters with 75 students and 26 students respectively. There were 12 students teams the first semester and 7 students teams in the second semester for a total of 19 home modification projects. Results of these projects however suggest two findings: 1) students reported high satisfaction with the results of group interaction between the two cohorts, and 2) home modification projects showed greater level of detail, more synthetic solutions and greater attention to the total environment. Architecture students contributed significantly to the understanding of the spatial layout using both conventional drawing techniques and the spatial syntax analysis. Occupational therapy students contributed to the overall description of functional performance for any patient group and better attention to individual patient performance of tasks in the home environment. Our results are not yet statistically calibrated for this experiment as we are still using formative evaluation to modify our approach to the problem.

Case Study 1: Myelomeningocele - Spina Bifida

Patient:
Age: 33, Sex: Male
Our patient has myelomeningocele – form of spina bifida. A portion of the spinal cord protrudes through the vertebral column and outside the body and is often enclosed by a meningeal membrane (fluid-filled protective sac)
Protruding spinal cord and associated nerves are damaged and/or under-developed. Myelomeningocele is the most severe form of spina bifida.
During the visit to Adriana's home, the following observations were made:
Patient lives with his family.
The majority of the home was modified to his disability.
Each doorway to his bathroom and bedroom is extended wall to wall.
The toilet is adjacent to a bathing bed which is also adjacent to the bathtub.
The bathroom sink is depressed to his height which is 44 inches on the wheelchair.
The living area is an extension to the existing house.
The area can be accessed from the house and the outside of the space.

The team determined that most significant problems are encountered by the patient in the Kitchen. Problems in the Kitchen are:
The counter height is too high for wheel chair access – only one table available.
Cabinets above table create space separation.
No access to kitchen amenities.
Not able to sit at bar.
Doesn't want to feel separated from Dining Room.
After a spatial syntax analysis and home assessment, proposed modifications included:
Removal of cabinets above table in order to open up space
Extension and rotation of existing table to allow for more counter access to client
Addition of wheelchair lift for client to allow for interaction with people at bar level
Pull out drawers for easy access
Space under counter accounts for wheelchair dimensions

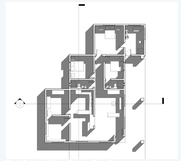


Fig. 5 Existing Home Plan for Team 3

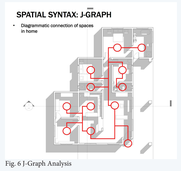


Fig. 6 J-Graph Analysis

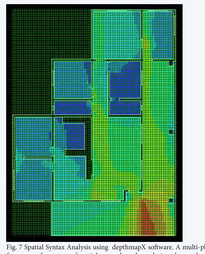


Fig. 7 Spatial Syntax Analysis using depthmapX software. A multi-platform software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. It works at a variety of scales from building through small urban to whole cities or states. At each scale, the aim of the software is to produce a map of open space elements, connect them via some relationship (for example, intervisibility or overlap) and then perform graph analysis of the resulting network. The objective of the analysis is to derive variables which may have social or experiential significance. [http://www.spacesyntax.net/software/] Spatial analysis included only the degree of visual integration (V_i). Red areas indicate highest degree of integration and dark blue is the lowest.

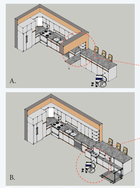


Fig. 8 Axonometric representation of existing plan layout for Kitchen (A) and modification based on spatial analysis (B). The modification presents a more integrated spatial configuration based on fewer visual and physical barriers for a patient with mobility impairment. Fig. 9 identifies key points of difficulty identified using the spatial syntax analysis.

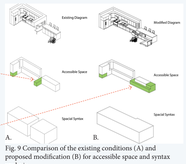


Fig. 9 Comparison of the existing conditions (A) and proposed modification (B) for accessible space and syntax analysis.

Case Study 2: Tetraplegia

Patient:
Age: 25, Sex: Male
Our patient suffered a C5C6 spinal chord injury at age 22. On January 29, 2011, Patient B was seriously injured during a tackle while playing rugby for Florida Atlantic University in a game against the University of Miami. Then just 22, he sustained a complete cervical spinal cord injury that rendered him paralyzed from the chest down. After being successfully operated on he began his recovery process. He healed rapidly in ICU and Acute Care where he was transferred to Jackson Rehabilitation Hospital as an inpatient for two months.
The client operates in his wheel chair 24/7. He has a designated wheelchair to take in the shower and another for all day use. He uses a catheter for convenience. He uses tools and touchscreens to complement his limited hand function.
Tetraplegia, also known as quadriplegia, is paralysis caused by illness or injury to a human that results in the partial or total loss of use of all their limbs and torso; paraplegia is similar but does not affect the arms. The loss is usually sensory and motor, which means that both sensation and control are lost.
Symptoms, signs and complications. Although the most obvious symptom is impairment to the limbs, functioning is also impaired in the torso. This can mean a loss or impairment in con- trolling bowel and bladder, sexual function, digestion , breathing and other autonomic functions.

During the visit to his home, the following observations were made:
He lives alone.
The bathroom and bedroom area presented him with the most problems performing activities of daily living.
The medicine cabinet was difficult for him to reach.
The bed was not a good height.
He is not able to reach the closet.
He had difficulty in the bathroom area with the shower and toilet.
Team determined that all living areas of the apartment presented problems.
After a spatial syntax analysis and home assessment, proposed modifications included:
Removal of cabinets above table in order to open up space
Re-configuration of bathroom and bedroom to allow for continuous open space for ease of movement.
Addition of lift to aide in transfer from wheelchair to bed and wheelchair to toilet.
Open closet configuration for ease of access.
Kitchen counter modified for a linear arrangement with continuous surface with accessible heights for appliances and sink.
Integration of entertainment devices and Dining Area surfaces for ease of use .

Fig. 10 Existing Home Plan for Team 1

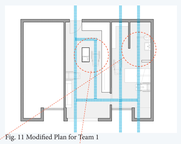


Fig. 11 Modified Plan for Team 1

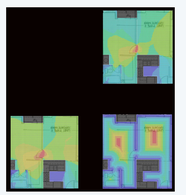


Fig. 14 Spatial Syntax Analysis using depthmapX software. A multi-platform software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. It works at a variety of scales from building through small urban to whole cities or states. At each scale, the aim of the software is to produce a map of open space elements, connect them via some relationship (for example, intervisibility or overlap) and then perform graph analysis of the resulting network. The objective of the analysis is to derive variables which may have social or experiential significance. [http://www.spacesyntax.net/software/]. Spatial analysis included the following factors: (a) the degree of Connectivity, (b)visual integration (V_i) and (c) visual density (V_d). The red areas indicate highest degree and dark blue, lowest for each category.

Fig. 12 Visual relationships for proposed modifications to Bathroom and Bedroom. Note the linear progression from bed to bath in both plan and visual environment.

Fig. 13 Visual relationships for proposed modification to Kitchen and Dining Area. The linear relationship addressed problems noted in the spatial syntax analysis along both the V_i and Connectivity dimensions.

Discussion

Fig. 15 Survey graphs for Q. 5-12 in survey, shown as Q. 1-8 here.

A post-class evaluation survey was administered for the first semester the course was offered. The survey was given after the presentation of the final home modification project. A total of 35 students participated or 45% of students in the course. Students were asked to report 1) basic information including their program, group affiliation, time spent on class projects and number of times they met with their team (4 questions total). They were additionally asked (Q. 5-12) to self-report on their perceptions of the experience of working together (see Fig. 15-16). One additional question asked "How could we improve the team exercises?". The questions were weighted to toward concerns about coordination between group members and assessment of group participation (8 out of 12 questions). Results were mixed, but overall teams reported positively for Q01: My team worked well together (52.17% agree for ARC, 60% strongly agree for OT).
There was stronger correlation for both groups between assessed benefits (OT 42.86% and ARC 39.13% strongly agree) and positive perception of the learning experience (less that 2% mean for both groups).

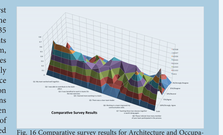


Fig. 16 Comparative survey results for Architecture and Occupational Therapy students for Q. 5-12 (shown as Q1-8 in this graph).

Conclusion and Outlook

1.1 General Method: Based on the formative evaluation of the current projects, we anticipate additional analysis to generate a better understanding of the relationship between the Home Assessment and the spatial configuration analysis. The spatial maps offer three significant dimensions of spatial calibration: 1) Connectivity, 2) Visual Integration (VI), and 3) Visual Density (VD). The study primarily taken into consideration connectivity, but further iteration would allow for better control of the impact of the three dimensions on the proposed home modifications. For the Research Q1 we do not yet have adequate data to determine a clear correlation between the home analysis tool used and the spatial syntax modeling. For Research Q2, the student survey results and the case study examples indicate clear improvement in the following areas: 1) home modification proposals are more wholistic and address significantly more aspects of patient functional disability than home modifications without spatial analysis, 2) students groups (architecture and occupational therapists) both benefit from the collaborative project in communication, cooperation and overall learning experience. Next steps include: 1) more stringent control for variation between groups, 2) analysis using all three dimensions of the spatial syntax model, 3) additional comparison between the Home Assessment Tools used and the spatial syntax modeling, and 3) larger pool of patients.

1.2 Method in Spatial Syntax: Spatial perception is a complex constellation of sensory and psychological components. There are various theoretical models under which an experimenter can operate when design an evaluative framework for how to calibrate the spatial context for human movement. There are two potential theoretical models for this study: 1) cognitive mapping: typically done on a large scale, but could be done on a small scale – size of a single space or small area, and 2) ecological (environmental) psychology to classify different types of spaces (information-based perception, embodied cognition). Our methodology for calibrating spatial context will depend on the theoretical framework used to classify what is happening in perception. This will have to be considered as we develop our spatial syntax.
Spatial syntax involves three basic conceptions of space: isovist, axial and convex. Isovist measures the field of view from any particular point in an enclosed space. Axial space uses the straight sight-line method that finds the minimal distance between two points along a straight line as illustrated in Figure 1. The convex approach assumes that a given space is a bounded void where no line between any two points is outside of the perimeter and all points within the polygon are visible to all other points. Typically this analysis is applied at much larger-scale spaces. We will modify and test at the micro-scale surrounding simple gestures like retrieval of a glass, or moving a book from a one position to another. The advantages of the axial method are 1) it's relative simplicity, and 2) we will be able to modify it for simple spaces appropriate to the experimental set-up.

Questions will naturally arise and some are present from the start: Is it possible to calibrate intelligible spatial differences? Can we test for differences in groups without knowing how they perceive the context? What is the size of the frame of reference – a single gesture? A constellation of gestures and/or movements (for instance, getting out of bed)? or an association of constellations that include navigating several tasks? By developing an experimental approach that includes spatial context from the beginning we will be able to test for the role of context on the perceptual memory of patients with stroke. We hope to develop a methodology that can be applied to a broader segment of the population of patients with neurological disorders.

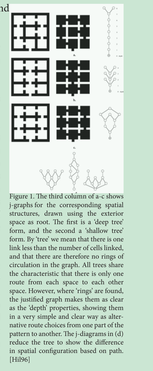


Figure 1. The third column of a-c shows J-graphs for the corresponding spatial structures, drawn using the exterior space as root. The first is a 'deep tree' form, and the second a 'shallow tree' form. By 'tree' we mean that there is one link less than the number of cells linked, and that there are therefore no rings of circulation in the graph. All trees share the characteristic that there is only one route from each space to each other space. However, where 'rings' are found, the justified graph makes them as clear as the 'depth' properties, showing them in a very simple and clear way as alternative route choices from one part of the pattern to another. The J-diagrams in (d) reduce the tree to show the difference in spatial configuration based on path. [Hil96]

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