Healthy young individuals navigating in a community environment of the mall: a visuomotor perspective.

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STATEMENT OF AUTHORSHIP

I, Hayati Bharatkumar Joshi, certify that I am the primary author of this thesis. I claim full responsibility for the content and style of the text included herein.

STATEMENT OF ORIGINALITY

This thesis contains no material that has been published elsewhere, except where specific references are made. The study presented in chapter 3 is original material and represents contributions to knowledge in the fields of locomotion, vision and rehabilitation. In this work, I have used a living lab approach to assess gaze behavior amongst healthy young adults while walking, a topic that has not been studied despite its relevance to the safety and independence during community ambulation. In this study, gaze behavior of participants is assessed while exposed to pedestrians approaching from different locations and directions in a shopping mall. Most of what we know about gaze behavior during locomotion is derived from findings collected in a controlled laboratory setting. This study thus addresses a large knowledge gap on the control of gaze behavior in a real-world setting, with all the diversity and richness of pedestrian exposure that it entails. The information that emerged from this study furthers our understanding by establishing metrics to quantify gaze behavior in a community setting during ambulation. The results of this thesis also provide valuable information for the design of future research studies and clinical interventions in populations with altered community ambulation skills, such as older adults and people with stroke.

The data presented in this thesis was collected at Alexis Nihon Mall, Montreal, Canada and was processed at the Feil & Oberfeld Research Centre of the CISSS-Laval and Jewish Rehabilitation Hospital Site of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR), affiliated to McGill University. The study presented in this thesis was approved by the Research Ethics Board of CRIR.

DEDICATION

I dedicate this thesis to my parents, to whom I owe everything. To my mother, Dr. Trupti Joshi, there are no words that could describe your devotion to your family. I still cannot comprehend how you have managed to accomplish all that you did. Having a full-time job, taking care of Baa, and still being a single parent that was always present and attentive to every detail of the lives of your two quite demanding children. To my departed father, Bharat Joshi, for offering me the best upbringing, the happiest childhood that one can ask for and for fostering my curiosity, passion for learning, and compassion for those in need. I am forever thankful for the continuous support, patience and love. You have taught me so much that even today I catch myself remembering your words and especially your actions, so they can teach me even more. To my brother, Tathya Joshi, for always believing in me and motivating me to push my boundaries. Had it not been for you talking to mom about my ambition to study in Canada, I would not have had the courage to step a foot out of my comfort zone, and I deeply thank you for having that confidence in me. Although being younger to me, you have inspired me at many phases in our life that we grew together, and you make me swell with pride. I love you more than anything.

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CONTRIBUTION OF AUTHORS

This thesis is presented in a manuscript format and includes one research manuscript, which has been formatted for publication in a peer-reviewed journal. I, Hayati Bharatkumar Joshi, am the main contributor and lead author of all chapters and the manuscript included in this thesis. My contribution extends to the research design, experimental set up, data collection, data analyses, statistical analyses, interpretation of findings, preparations of figures/tables, submission for publication, revisions following peer review and writing of this thesis.

The research project and manuscript presented here were developed under Drs. Anouk Lamontagne's and Philippe Archambault's supervision. Dr. Lamontagne oriented the selection of the research design, experimental set up, data analysis, statistical analysis, interpretation of findings and critically reviewed and provided constructive feedback on this thesis. Dr. Philippe Archambault provided constructive inputs on the experimental design, data collection and analysis, statistical analysis, interpretation and critically reviewed this thesis.

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ABSTRACT

Locomotion primarily relies on the coordination of gaze and body movements. However, community ambulation has complex requirements involving multiple sensory stimuli and obstacles, which modulate gaze behavior and obstacle circumvention strategies. There is limited data on gaze behavior during pedestrian circumvention, and findings from laboratory environment may not be representative of everyday behavior. The focus of this thesis was thus to characterize gaze behavior in healthy young adults during obstacle circumvention when ambulating in a community environment. It was hypothesized that, despite the complexity of a community environment, healthy young adults will exhibit stereotyped gaze behavior which are modulated as a function of contextual demands such as the location and direction of approach of other pedestrians present in the environment. A shopping mall in downtown Montreal was used as a living lab to study gaze behavior of participants under ecological “rules”, where the participant and other mall users (pedestrians) interact in real time.

This is an observational, exploratory study where twelve healthy young individuals (18-29 years) with right-handedness were recruited. The participants were assessed in one session while walking from a pre-set starting location to a goal located at 20m. They were exposed to multiple moving pedestrians with varied location and approaching direction. A motion capture system comprising of wearable inertial sensors (APDM) was used to record full body kinematics. An eye-tracker (Tobii Glasses Pro 2) was used to record participants’ eye movements.

Participants thus exhibited more gaze episodes on pedestrians (GEP) and longer total duration of all GEPs on receding vs. looming pedestrians, that is those walking away vs. towards the participant. However, there was a trend for an increase in the relative (percent) duration of all GEPs for looming pedestrians, possibly implying a prioritization of gaze allocation according to perceived risk of collision. Also, a farther distance at onset of first GEP

was observed for looming pedestrians, possibly to foresee a risk of collision with approaching pedestrians by localizing them afar. A rightward bias was present in the distribution of seen pedestrians, even though there was an equal distribution of pedestrians on both sides. This finding may be attributed to a visual-attentional bias towards the right side, the right-handedness of the individuals and the right-side traffic rule adopted in North America. The pedestrians on the right had longer duration of first GEP, while for all GEPs those on the center were looked at longer. This indicates that the pedestrians were first scanned on the right side, perhaps to account for the traffic rule, to plan a collision avoidance strategy. It however makes sense that all GEPs were directed for a longer duration towards receding pedestrians in center, since they remained in the field of view for a longer period.

This thesis fills important knowledge gaps in the literature on gaze behavior among healthy young adults while ambulating in a community environment. Results provide evidence that gaze behavior modulates as a function of pedestrian characteristics, i.e. their location and approaching direction. This modulation of the gaze in particular seems to be a function of the perceived risk of collision, where looming pedestrians were considered to be at a higher risk. This thesis provides us with metrics and a basis for comparison to characterize gaze behavior in other population groups presenting visuomotor control impairments and reduced community ambulation abilities such as older adults and individuals with physical disability (e.g. stroke).

ABRÉGÉ

La marche repose sur la coordination du regard et des mouvements du corps. Cependant, la marche en communauté a des exigences complexes impliquant de multiples stimuli sensoriels et des obstacles qui modulent le comportement du regard et les stratégies de contournement d'obstacles. Il existe peu de données sur le comportement du regard lors du contournement de piétons et les résultats obtenus en laboratoire ne reflètent pas nécessairement le comportement dans la vie quotidienne. L'objectif de cette thèse était de caractériser le comportement du regard chez de jeunes adultes en bonne santé lors du contournement d'obstacles dans un environnement communautaire. L'hypothèse était que malgré la complexité de l'environnement communautaire, les participants présenteraient un comportement du regard stéréotypé qui est modulé en fonction des exigences contextuelles telles l'emplacement et la direction d'approche des autres piétons présents dans l'environnement. Un centre commercial a été utilisé comme laboratoire vivant pour étudier le comportement du regard des participants selon des "règles" écologiques, où le participant et les autres utilisateurs du centre commercial interagissent en temps réel.

Il s'agit d'une étude exploratoire et d'observation dans laquelle douze jeunes individus en santé (18-29 ans) avec droitiers ont été recrutés. Les participants ont été évalués au cours d'une session alors qu'ils marchaient d'un point de départ vers un but situé à 20 m. Ils ont été exposés à de multiples piétons en mouvement dont l'emplacement et la direction d'approche variaient. Un système portable de capteurs inertiels (APDM) enregistrait la cinématique du corps entier tandis qu'un système de vidéo-oculographie (Tobii Glasses Pro 2) a permis d'enregistrer les mouvements des yeux.

Les participants ont présenté plus d'épisodes de fixation du regard sur les piétons (ERP) et une durée totale plus longue de tous les ERP pour les piétons s'éloignant vs. se rapprochant des participants. Cependant, on a constaté une tendance vers une durée relative plus longue de tous

les ERP pour les piétons qui se rapprochaient, suggérant une priorisation de l'allocation des ERP en fonction du risque de collision perçu. De même, une distance plus grande a été observée au début du premier ERP pour les piétons qui se rapprochaient vs. s'éloignaient, possiblement pour localiser à plus grande distance les piétons en approche et ainsi mieux prévenir une collision. Un biais vers la droite était présent dans la répartition des ERP, malgré une répartition symétrique des piétons. Ceci pourrait être attribuée à un biais visuel-attentionnel vers le côté droit, au fait que les individus étaient droitiers, de même qu'à la convention de circulation du côté droit observée en Amérique du Nord. Les piétons du côté droit étaient regardés pour une plus longue durée au premier ERP. Considérant tous les ERP, par contre, ceux du centre étaient regardés plus longtemps. Les piétons ont donc été visualisés du côté droit en premier, peut-être dû à la convention de circulation à droite en Amérique. Il est cependant logique que l'ensemble des ERP aient été orientés plus longtemps vers les piétons du centre, ceux-ci étant restés plus longtemps dans le champ de vision.

Cette thèse comble d'importantes lacunes dans la littérature quant au comportement du regard lors de ma marche dans la communauté. Les résultats démontrent que le comportement du regard se module en fonction des caractéristiques des piétons telles leur position et leur direction d'approche. Cette modulation du regard semble notamment être fonction du risque de collision perçu, les piétons en approche étant considérés comme plus à risque. Cette thèse nous permet aussi d'établir une base de comparaison pour caractériser le comportement du regard auprès d'autres populations présentant des troubles visuomoteur ou de la marche en communauté, comme les personnes âgées et celles ayant subi un accident vasculaire cérébral.

THESIS ORGANIZATION AND OVERVIEW

The organization of this manuscript-based thesis adheres to the guidelines for thesis preparation published by McGill Graduate and Postdoctoral Studies.

CHAPTER 1: INTRODUCTION

1.1. COMMUNITY AMBULATION

Walking is a critical element for determining independence, a prime attribute of quality of life and is essential for the completion of many basic activities of daily living (BADLs) (1). Independent ambulation requires critical elements such as the maintenance of upright posture against gravity, balance, cardiovascular endurance, strength in the lower limb, and the ability to create a coordinated and recurring pattern of lower limb movement responsible for forward progression (2). When it comes to community ambulation, however, the locomotor pattern further needs to be adjusted to cope with environmental demands. Patla et al. (1999) suggested that the physical requirements linked to community mobility are complex, modulated by environmental demands and are not limited to the internal variables like speed and distance (1). They proposed a conceptual model of the eight dimensions of mobility in which attributes of the physical environment were grouped into 8 categories, referred to as "dimensions". These dimensions represent the external demands that have to be fulfilled by an individual to be mobile in a community environment. The dimensions are: minimum walking distance, time constraints, ambient conditions, terrain characteristics, external physical load, attentional demands, postural transitions and traffic level (1-3).

Of the dimensions above, traffic level is of special interest in the context of this research proposal where I will be examining the strategies used to walk in a community environment while successfully avoiding collisions with surrounding pedestrians to ambulate safely. Traffic density is a crucial aspect of safety when walking in a community and it can be worded as the average number of people within one arms range, which determines the need for collision avoidance (2, 3). Obstacle circumvention involves a successful aversion and veering from both static and dynamic obstacles while ambulating in a community environment, where dynamic obstacles are more commonly encountered as compared to static obstacles. While walking in a dynamic environment, an individual has to anticipate the walking path of an approaching person and modify his own path and/or his walking speed (e.g. speeding up, slowing down, or stopping) in order to avoid collisions. A study conducted by Huber et. al (2014) focused on the adjustments of path and speed when a pedestrian is crossing a human interferer at different angles and speeds (4). They found that crossing at acute angles (i.e. 45° and 90°) seems to require more complex collision avoidance strategies involving both path and speed adjustments while crossing at obtuse angles (closer to 0°) presented only path adjustments. A study looking at human v/s non-human virtual obstacles performed by Silva et. al. (2018) showed that the nature of obstacle also contributes in shaping obstacle avoidance strategies and changes in speed during locomotion (5). Thus, collision avoidance strategy is modulated as a function of obstacle characteristics e.g. approaching direction.

Locomotion heavily relies on vision, which is the only human sensory modality capable of providing information about distant environmental features, other than sound through which some spatial information about the environment can be acquired (6-8). Gaze activity provides a good indication of where humans derive their visual information from, while the coordination of gaze and body movements helps understand the control of locomotion for steering (e.g. changing direction) and obstacle circumvention (1, 9). Gaze orientation is the result or sum of head and eye orientation and it is used to gather visual information that allow modulating the gait pattern in a feedforward manner, that is in anticipation of features and potential perturbations in the environment (8). Kinematic strategies implemented during locomotion are the various approaches which are incorporated by the body to move sequential body segments with respect to one other. These are also implemented in a feedforward manner (8, 10, 11). It suggested that the nature of the visual information, as well as gaze behavior and kinematic strategies differ when steering towards a goal vs. when circumventing an obstacle (12).

1.2. GAZE AND KINEMATIC STRATEGIES FOR LOCOMOTOR STEERING

Locomotor steering is the action of changing direction while walking (13), which is essential if one wants to get to the desired destination. Most studies examining steering strategies have looked at the whole body and/or head movement to infer where the eyes were targeted, whereas few studies have actually examined the pattern of eye motion. Amongst the latter, the analysis are primarily limited to the horizontal component of eye movements (1, 14). Hollands et al. (2002) examined gaze behavior in healthy young adults using an Applied Science laboratory (ASL) eye tracker (eye and scene camera mounted on the helmet) as participants walked in the laboratory at their natural pace along a 9 m travel path and were visually cued to turn towards a direction (8). The gaze behavior was categorized as: (a) fixation on a location or object, (b) travel fixation or, (c) shift in gaze from one location to another. Fixation was defined as the stabilization of gaze on a location in the environment for three frames (99.9 ms) or longer. Travel fixation was defined as a shift in gaze caused by whole body movement (minimum duration of three frames). It was observed that the gaze was stabilized at a constant distance in front of the participants' body and moved in the same direction and at the same speed as locomotion. Also, a gaze shift was noticed with saccadic eye movements, where saccades were rapid eye movements (between two and four frames in duration) causing a shift in gaze between two locations. They concluded that participants invariably made saccadic eye movements to align gaze with the future travel destination which was then accompanied by head reorientation. Thus, anticipatory head movements are generated in coordination with eye movements as part of the gaze reorientation process and this plays an important role in the steering of locomotion (8).

Hollands et al. (2002) examined the temporal sequence of body segment reorientation when participants were visually cued to change their walking direction (8). It was seen that the participants' gaze was consistently aligned with environmental features lying in their current plane of progression; and the mean latency of reorientation onset with respect to cue delivery was 326 ms for the eye and 349 ms for the head. In other words, the eye turns first and then the head realigns to the new travel path. They also determined the effect of immobilizing the head (by fixing it to the trunk) on this sequencing pattern and found that it resulted in the early onset of trunk yaw reorientation with respect to the cue to turn, thereby realigning the head with the new travel direction in a faster time, which suggests that there was a compensation for the loss of independent head mobility. Thus, alignment of head with the new travel direction prior to repositioning the rest of the body is not simply a consequence of body reorientation but is an important component of the steering strategy (8). This result concurred with previous findings of Grasso et al. (1996, 1998), Patla et al. (1999) and Imai et al. (2001) that the head turns first in the new travel direction before the rest of the body (1, 8, 10, 14, 15).

Imai et al. (2001) added on this concept by performing a comprehensive three-dimensional analysis of body, head and eye movement pattern of participants, where they had to walk along a straight line for 3 m and turn 90° along a straight line for 3 m (15). The results showed that the compensatory eye, head, and body movements stabilize gaze in the direction of forward motion during straight walking and direct gaze in advance of the heading trajectory during turning. Further, they saw that there was a sinusoidal yaw of the body which was opposite to head yaw when the trajectory was also approximately sinusoidal. Although head yaw in space was small, it compensated for the lateral translation of the body and head to stabilize gaze in space. Thus, not only are eye movements redirected to the new travel path in an anticipatory fashion, but they also compensate for translational and rotational head movement in space. The main purpose of these compensatory head movements would be to stabilize the image on the retina, thus facilitating the uptake of visual information (15). Thus, a hierarchical schema was established whereby an optical image of an ambulatory goal is first visually fixated with the help of saccadic eye movements thereby providing a gaze-centered frame of reference, which can then be used to align the head with the goal by horizontal reorientation (yaw). This head realignment, in turn, provides the CNS with a head-centered frame of reference that is used to control trunk reorientation (yaw) (8).

The literature also suggests that different types of visual cues can be used to guide locomotor steering. In a seminal study, Warren et al. (2001) used virtual reality to manipulate the amount of optic flow (e.g. visual motion information available to the eye of the observer) during a locomotor steering task in healthy young individuals (13). The authors demonstrated that individuals use both optic flow (optic flow-based control) and the location of the goal (egocentric direction control) to guide goal-directed locomotion. The relative weighting for each strategy changes depending on the environmental structure. Another study carried by Hollands et. al (2002) using an eye tracker looked at the orientation strategy where gaze was consistently directed along the locomotor axis and the results were consistent with the suggestion of Warren et al. that both egocentric control and optic flow information are used in the normal guidance of locomotion (8). Jovancevic-Misic et. al (2009) further showed that gaze is drawn towards task relevant aspects in the environment, for instance, walkers fixated their gaze on locations where they would eventually step, in order to gain maximum information for a safe foot placement (16). Thus, locomotion steering relies upon the visual input of the surroundings and also on one's own egocentric control of locomotion, which is with the integration of body segmental reorientation of head and trunk.

1.3. GAZE AND KINEMATICS STRATEGIES FOR OBSTACLE CIRCUMVENTION

The above studies looked at the kinematic strategies observed during locomotor steering in locomotion, in other words, ambulating and changing direction in the absence of obstacles on the travel path. The first study to demonstrate differences in locomotor behavior during steering vs. obstacle circumvention what that of Vallis et. al (2003) (12). In that study, the authors studied the anticipatory locomotor adjustments employed while circumventing a ground-based obstacle (cylinder) placed in the travel path. In contrast to findings observed in other studies examining locomotor steering, they found no typical sequence of body segment reorientation (where the head would be first reoriented towards the new travel direction, followed by the rest of the body). They concluded that ‘circumventing an obstacle requires a different coordination for a transient change in COM trajectory with the underlying travel-direction maintained’. These findings indicate that the coordination of body segments during locomotion is task specific and related to the goal of the locomotor task and environmental constraints present (12).

Since the study of Vallis et. at (2003) (12), many other groups have examined kinematic strategies during obstacle circumvention (9, 17-20). From these studies, it emerges that the changes in body segment reorientation and travel path are implemented to maintain a certain distance from the obstacle, which has been referred to as minimal clearance, personal space or safety zone. According to Gérin-Lajoie et. al (2005), this personal space would represent an elliptical protective zone around their body across different environmental contexts, which is adjusted to deal with environmental factors such as obstacle movement, certainty about obstacle movement, and auditory distractions (17). This ensures sufficient time to perceive upcoming hazards and to perform gait adaptations in accordance with the environmental setting.

In the literature, there are some theories on locomotion in a complex environment, where obstacle circumvention is being studied to be controlled by various visual cues like bearing angle, optic flow, etc. used to apply to a wider range of tasks involving multiple moving objects (18). The bearing angle (BA) model is a widely adopted model of collision detection, obstacle avoidance and interception, where the bearing angle is the angle between the object and reference direction that remains fixed in exocentric coordinates (dashed line). By keeping the bearing angle constant, the observer and the object are on a collision course and thus, the observer will eventually intercept the moving target. And so the observer should change speed or direction (or both) for avoiding a collision (18).

On a same note, Optic flow is also said to control the visual guidance of locomotion (13, 21). Optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and a scene (22). Bühler and Lamontagne (2018) examined the circumvention strategies of participants in response to pedestrians approaching from different directions in the virtual versus physical environment (20). The results showed that participants walked slower maintaining a larger minimum distance from the interferer in the virtual environment highlighting the potential difference due to a change in the nature of optic flow.

Amongst the other studies on obstacle circumvention, there were few studies that had actually quantified gaze behavior. Olivier et. al (2012) carried out a joystick-based navigation and interaction study with virtual walkers highlighting risk of collision as a salient visual cue, and came up with an approach to quantify the risk of collisions in an interaction neighborhood with distance- and time-based metrics such as the Distance at Closest Approach (DCA, also referred to as Minimal Predicted Distance -MPD) and the Time to Closest Approach (TtCA), which were an interesting descriptor of the dynamics of interaction between two walkers (9, 23, 24). These metrics were used to portray collision avoidance strategies and it stated that, it is typically the lower values of TtCA or DCA which correspond to an increased need of avoiding collisions. However, it is challenging to quantify this necessity to interact with a walker (for an instance, low TtCA with high DCA where no action would be required) and should incorporate both distance- and time-based metrics. They combine these metrics and ranked the risk of collision of each virtual walker using Pareto optimality, which is a granular method to rank cases based on the combination of two parameters, i.e. distance and time to closet approach. The results indicate that most of the gaze fixations were directed towards the virtual walkers with the highest risk of collision (higher pareto rank) with the participant, suggesting that risk of collision is salient and influences the gaze behavior of the participants (9). These findings support earlier observations of Jovancevic-Misic et. al (2009) who studied the gaze behavior during pedestrian circumvention in a virtual environment, it was shown that gaze fixation changes depending on the perceived risk of collision, where the interferers who are most likely to cause a collision would draw more attention compared to those who are less likely to create a collision (16).

As the above-mentioned studies well demonstrate that obstacle avoidance is driven by the obstacle characteristics for e.g., the factor of risk, it is important to examine this aspect further. As dynamic obstacles in the environment have more leverage over static obstacles when it comes to imposing risk, our focus was to characterize the obstacles (pedestrians) in this study on the basis of risk, which resulted in categorizing them on the basis of their approaching direction to the participant. It was in our interest to also look for any possible asymmetry in the perception of obstacles (unequal time spent looking at obstacles in different visual fields) while ambulating in the evaluation setting. This supposition is due to a marked observation in the presence of an asymmetry in obstacle avoidance as seen by Gérin- Lajoie et al (2008) which shows that right-handedness maintains a smaller right personal space during leftward obstacle circumventions (25). And also, a reported asymmetry from the study by Silva et. al (2018) which stated that participants veer more to the right when avoiding human obstacles as opposed to non-human obstacles (5).

CHAPTER 2: RATIONALE AND OBJECTIVES

2.1. RATIONALE

There is very limited information on the extent as well as timing or distance from which pedestrians are being looked at during a collision avoidance task. Moreover, several studies in the literature have described gaze behavior in the presence of various visual cues and with different adaptions during locomotion. Such studies took place in a controlled laboratory or a virtual setting. They were done by regulating the density and motion (direction, speed) of obstacles, whether they were objects or pedestrians. Nevertheless, in a community environment as opposed to a controlled lab setting, the density and motion described by dynamic obstacle is constantly changing with pedestrians looming vs. receding from and towards different locations. This should possibly affect gaze behavior and obstacle circumvention strategies, and for this reason, results collected in a controlled laboratory setting may fail to represent everyday life demands. This leaves us with a gap in knowledge about the actual visuomotor control requirements for successful pedestrian circumvention in the community setting. We know that day-to-day mobility mostly occurs in a community environment. But at the same time, there is very limited data on gaze behavior and its potential impact on the uptake of visual information, which is essential for circumventing around dynamic obstacles in a complex environment. Current research is also yet to come up with metrics which will be used for quantifying gaze behavior in such complex walking tasks as experienced during community ambulation, which arises the need to study this human navigational characteristic.

2.1.1. LIVING LAB APPROACH

A living lab approach is the concept of using a community setting, such as a shopping mall, for research purposes, which involves a public- private- people partnership, enabling consumers (e.g., users) to take active roles as contributors and co-creators in the research, development and innovation process. This approach highlights the advantage of replicating a real-world scenario, thus enabling easy implication of theories into practice. In 2011, the "mall as a living lab" project was established with the help of several people who came together thus providing investigators with access to a naturalistic setting for research in the mall (26).

From a rehabilitation perspective, the living lab approach has the advantage of aiding in removing barriers to social participation and independent living by improving inclusivity in a type of community environment (26). Also, community participation, such as the types of activities taking place in malls for instance, would create a positive impact on the health of individuals. It provides the participants with a sensory stimulation, safety, comfort, convenience, and social interactions just as one would normally have. This interaction within an environment eventually teaches patterns of behavior through socialization, contributing to the development of adaptive patterns of participation (26). In the specific context of this study, the main advantage of the living lab approach is the ability to study locomotor behavior in a context that is meaningful to the participants, and which incorporates the specificity and diversity of contextual demands typical of a community environment. This includes, amongst others, pedestrians of different characteristic approaching from different directions and who pays different levels of attention to their environment, the presence of sensory distractors, etc.

Consequently, we used a living lab approach, wherein gaze behavior was assessed as healthy participants ambulated in the shopping mall as a community setting. An environment such as the mall involves multiple and changing sensory stimuli (e.g. visual, auditory, with varying light levels, etc.) and challenges (multiple dynamic human obstacles of different speeds), which are for now difficult to replicate in a laboratory environment. In addition, a living lab such as the mall provides a unique opportunity to study navigation under ecological 'rules', where the participant (patient) and other mall users (potential moving obstacles) interact in real time. As this study was the first to measure participants' gaze behavior while walking in a real-life community environment, it focused on the development and evaluation of measures of performance (metrics) to quantify gaze behavior during community ambulation amongst healthy young individuals.

2.1.2. FUTURE SCOPE IN REHABILITATION

Community ambulation poses a challenge to individuals whose sensorimotor functions are compromised (11). In adults over the age of 65 years, the prevalence of impaired mobility is 7.7%, and the prevalence of impaired mobility rises to 35% in adults over the age of 80 years (3). In the presence of post-stroke sensorimotor impairments, for instance, both the control of locomotor steering (11) and that of obstacle circumvention (27, 28) are affected, which results in an additional challenge for them to ambulate in community environments. The results from this study will help in laying the foundation of gaze behavior metrics in healthy young population. This can later be used as a basis of comparison to that of a special population group, for e.g. healthy old adults or patients with physical disability and altered gaze as seen in stroke patients with visuo-spatial neglect (VSN). It will thus later help in acquiring knowledge about the contribution of an altered gaze behavior and its potential impact on the uptake of visual information essential to the control of such complex walking tasks.

2.2. OBJECTIVE AND HYPOTHESIS

2.2.1. OBJECTIVES

The primary objective was to characterize gaze behavior in healthy young adults during obstacle circumvention when ambulating in a community environment.

The secondary objective was to develop metrics to quantify gaze behavior during community ambulation.

2.2.2. HYPOTHESIS

Despite of the complexity of a community environment, healthy young adults will exhibit stereotyped gaze behavior which is modulated as a function of contextual demands (approaching direction and location).

Gaze behavior during collision avoidance with pedestrians in a community environment: a living lab perspective

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3.1. ABSTRACT

Background: Independent community walking relies heavily on the sense of vision and involves locomotor adaptations that are essential to avoid hazards in the environment (e.g. obstacles). However, little is known about the gaze behavior amongst healthy individuals while ambulating in a community setting. Our objective was thus to characterize gaze behavior of healthy young adults while walking and avoiding other pedestrians in a community environment. **Methods**: Twelve healthy young individuals (18-29 yrs.) with normal/ corrected visual acuity and right-handedness were assessed while walking from a pre-set location towards the goal at 20-meters distance, with exposures to several pedestrians with varied location and direction of approach. They were assessed in one session with an eye-tracker (Tobii pro 2) to record participants' eye coordinates and temporal distance factors were assessment using wearable sensors from a full body motion capture system (APDM). **Results:** Participants exhibited more gaze episodes on pedestrians (GEP) and total duration of all GEPs on receding pedestrians, however the relative duration of all GEPs exhibited a trend on looming pedestrians. These results, along with the fact that looming pedestrians were looked at a farther distance, imply a perceived risk of collision from looming versus receding pedestrians. Moreover, a rightward bias was also observed in the distribution of GEPs in the visual field, which could be linked to the dominance, handedness and also the traffic rule of the country. The pedestrians appearing on the right side had longer duration of first GEP, while those on center had larger number of GEPs and total duration of all GEPs. Cumulatively, they were also looked at from a farther distance as compared to those on the left side. There was a shift of GEPs in terms of duration from right to center, possibly to account for a change from an orientation to a monitoring strategy. **Conclusion:** Gaze behavior modulates as a function of the location and approaching direction of pedestrians in the mall. Indeed, while the rightward bias of GEP distribution observed in this study appears to reflect a rightward bias in visuospatial attention, gaze allocation on pedestrians remained modulated by factors such as the perceived risk of collision and the total visibility (both in terms of duration and location) of pedestrians in the observer's field of view. Results of this study furthers the understanding of gaze behavior during community ambulation, while establishing a benchmark for the quantification of defective visuomotor strategies in those individuals with mobility disorders.

Keywords: Gaze behavior, locomotion, living lab, pedestrian avoidance, rehabilitation

3.2. INTRODUCTION

The ability to move independently is a crucial element for determining the independence and quality of life of an individual (3). In everyday life, mobility activities are mostly carried out in complex environments, such as a community setting (e.g. street, shopping mall, etc.), and many environmental features influence its intricacy and difficulty (1, 2). Patla and Shumway-Cook (1999) identified eight dimensions or requirements of community walking, which included minimum walking distance, time constraints, ambient conditions, terrain characteristics, external physical load, attentional demands, postural transitions and traffic level (1-3). Our study tackles the requirement related to traffic negotiation, in particular pedestrian circumvention which is crucial to safely ambulate in a community environment. The ability to successfully avoid collision with moving obstacles or pedestrians can get challenging for older adults (3), and was shown to be compromised in people with physical disabilities (11, 27, 28), which emphasizes the need for further understanding of control mechanisms.

Locomotor adaptations as required for community walking heavily relies on the sense of vision, which is crucial to anticipate hazards and environmental challenges. In fact, other than sound through which some spatial information about the environment can be acquired (6, 7), vision is the only human sensory modality capable of providing information about distal environmental features (8). Visual information about the environment is gathered through changes in gaze orientation, which is achieved using coordinated head and eye movements in space. The coordination of gaze and body movements has been extensively studied in tasks such as locomotor steering. Common across all studies was the observation of a reorientation of gaze in the new travel direction, which preceded the change in walking trajectory or heading (8, 11, 14, 15, 29). Analysis of gaze behavior provided additional insight into the nature of visual information about the environment that is used to adapt locomotion, as well as the timing at which such information is gathered. When changing direction while walking, for instance, gaze is consistently reoriented in a feedforward manner towards the final goal, a behavior that is consistent with a use of visual cues such as the location of the optic flow's focus of expansion and that of the goal (egocentric direction control) to control locomotor steering (8, 13). In precision stepping tasks, gaze is drawn towards task-relevant aspects of the environment prior to stepping, such that walkers looked at the obstacles (obstacle crossing) and locations where they would eventually step (precision stepping) to ensure safe foot clearance and placement (8, 16, 30). Gaze strategies are further modified according to terrain complexity (29).

While the above-mentioned studies provided insights into the control of gaze behavior and the visual information guiding locomotion, there is a paucity of literature on gaze behavior related to obstacle circumvention and more specifically with regards to pedestrian interactions. Given different task requirements, head and body coordination differs in obstacle circumvention vs. other locomotor tasks such as steering (12). The nature of gaze behavior and visual information required for the successful completion of those tasks may vary accordingly. There are certain control parameters that specifically fuel obstacle circumvention and these are visually determined. First is the concept of safety margin or obstacle clearance, which is a distance maintained between self and the obstacle to maintain a protective space around the body while navigating through crowded environments. It is often also referred to as personal space or safety zone, and is modulated to plan gait adaptations with respect to the context of the environment (17). In the presence of a moving obstacle, the bearing angle, that is the angle between the object and reference direction in exocentric coordinates, would assist in determining whether the observer and obstacle are on a collision course, and whether an obstacle avoidance strategy (changes in speed and/or direction) is needed (18).

Amongst the different studies on obstacle circumvention, very few studies have actually quantified gaze behavior. In a study on pedestrian interactions, Jovancevic-Misic et. al (2009) found that gaze behavior changed depending on the risk of collision, where the risky interferers, that is those who were on a collision path, were looked at more frequently as compared to the non-risky interferers (16). Similar conclusions were drawn from a recent study involving joystick-based navigation and interactions with virtual walkers making risk of collision a salient visual cue (9). They formulated a metric called minimum predicted distance (MPD) which predicts the risk of collision. The walkers would adapt their motions only when the estimated value of MPD was too low (>1m), implying a risk of collision (23). Variables such as ‘Time to contact’ (31, 32) as well ‘Distance at closest approach’ and the ‘Time to closest approach’ (23) would also be used to quantify the risk of collision and need of an avoidance strategy between two walkers. In a preliminary study on eye and body movement coordination during pedestrian interactions while walking in a virtual environment, our group also showed that eye and gaze horizontal reorientation precedes changes in walking trajectory (33). While we hypothesized that the purpose of these eye and gaze movements were to localize the approaching obstacle and to assist in planning the future walking trajectory towards the goal, features of the environments which were actually looked at were not identified.

There also exists evidence in the literature that collision avoidance strategies are modulated as a function of the location/direction of approach of obstacles or pedestrians present in the environment (4, 9, 20, 34). The extent to which gaze behavior is modified accordingly, however, remains unclear. Furthermore, existing studies have described gaze behavior and various gait adaptions in a controlled laboratory or a virtual setting by regulating the density and motion (direction, speed) of the obstacles. In a community setting, however, the density and direction of the dynamic obstacles is constantly changing, with pedestrians looming vs. receding from and towards different locations. Therefore, results collected in a controlled setting may fail to represent everyday life demands, leaving us with a gap in knowledge on actual visuomotor control requirements for successful pedestrian circumvention in the community setting. Current research is also yet to come up with metrics for quantifying gaze behavior in a constantly changing environment, as experienced in the community.

In this study, we used a living lab approach whereby gaze behavior was examined as healthy participants ambulated in a shopping mall as a community setting. The living lab approach has the advantage of replicating a real-world scenario and providing the participants with sensory stimulation, comfort, convenience, and social interactions just as one would normally have in everyday life. The shopping mall as a location incorporated the specificity and diversity of contextual demands typical of a community environment, including pedestrians of different characteristic approaching from different directions and at different speeds, while paying different levels of attention to their environment. The mall also offered multiple and changing sensory stimuli (e.g. visual, auditory) and a natural setting where participants and other mall users interacted in real time, all this being difficult to replicate in a laboratory setting.

As this study was the first to measure participants' gaze behavior while walking in a real-life community environment, it focused on the evaluation and development of metrics to quantify gaze behavior during community ambulation. Therefore, our specific objective was to characterize gaze behavior of healthy young adults during obstacle circumvention in a community environment. We hypothesized that despite the complexity of a community environment, healthy young adults would exhibit stereotyped gaze behavior which are possibly modulated as a function of obstacle characteristics such as their location in space (left, center, right) and direction of approach (looming, receding).

3.3. METHODS

3.3.1. STUDY DESIGN

This is a descriptive cross-sectional, exploratory study where the participants' ability to walk towards a pre-determined location in the mall was examined in one session, lasting an hour.

3.3.2. PARTICIPANTS

A convenience sample of twelve right-handed healthy young adults between the ages of 18 to 29 years were recruited from McGill University, Montreal (Canada) while maintaining a male to female ratio of 1. On average, participants were aged 27 ± 2.6 years (mean ± 1SD) and presented a weight of 65.6 ± 6.8 kg and height of 165 ± 7 cm. Right-handed participants with scores equal to +40 or more were recruited as per the Edinburgh handedness inventory (35), since handedness was shown to have an influence on the visual-spatial and navigational abilities (36, 37), and since right handers represent 80% to 90% of the population (37, 38). Participants presented normal or corrected-to-normal visual acuity, with scores equal or above 20/20 as measured by the EDTRS visual acuity chart (39). Also, to control for the impact of cultural factors, participants only from countries with a right-side traffic rule were recruited in this study. Participants were excluded if they presented any condition interfering with locomotion (e.g. orthopedic, rheumatologic or neurological), lower limb or back pain, as well as any visual condition interfering with visual perception (e.g. strabismus, color blindness, etc.). The study was approved by the Ethics Committee of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR) and all participants gave their informed written consent.

3.3.3. EXPERIMENTAL SET-UP AND PROCEDURE

Data collection took place at the Alexis Nihon Mall located in downtown Montreal. Participants were assessed while walking and wearing a portable eye tracking system and wearable movement sensors. More specifically, the Tobii system (Tobii Pro Glasses 2) was used to record participants' eye in head movements. The Tobii system is a lightweight discrete glasses-mounted eye tracker with 90° viewing angle, wirelessly connected to a recording tablet. The head unit also comprised of a forward-mounted (scene) camera allowing the recording of point of gaze on the environment. Gaze was measured from both eyes at a sampling frequency of 25 Hz and resolution of 1920 x 1080 pixels, for each eye.

An APDM motion capture system (Ambulatory Parkinson's Disease Monitoring) that comprised of fifteen lightweight inertial sensors (gyroscope, magnetometer and accelerometer) positioned on the head, trunk, pelvis and bilaterally on the arms, hands, legs and feet were used to measure body kinematics. The APDM system was developed and validated for the measurement of locomotion and various gait parameters (40). It also has a wireless range from 20-50 meters and allows recording at a sampling rate at 128 Hz (41). Brief audio signals were emitted by the APDM system at the beginning and end of recording. These signals were recorded by the Tobii eye tracking system and later used for an offline synchronization of data recorded with the two systems.

Participants were assessed in a straight-line corridor (30 m in length and 8 meters in width) in the mall, leading to a subway entrance so as to ensure a continuous flow of pedestrians (Figure 3-1). They were assessed from a pre-set starting point (located in the middle of the hallway, at 10 m) to a final goal which was the sign for the subway entrance. These two pre-set locations were 20 m apart and ensured a clear visibility of the end goal from the starting position. Participants were instructed to walk at their comfortable speed for a community environment. A member of the team helped them locate and visit the area prior to the data collection. Participants performed 5 trials and were allowed to rest as often as needed throughout the evaluation.

3.3.4. DATA ANALYSIS

The combination of scene camera and eye-tracking sensor allowed to record the point where the eyes were directed along the horizontal and vertical planes with respect to the environment, as viewed on the video file. Further analyses of gaze behavior were carried out using a custom-made software, Clair Mobility which was developed by co-author WC (42).

The primary outcome measure was the relative (%) duration of gaze episode on pedestrian (GEP). Secondary outcomes included the number of GEPs as well as the total duration of all GEPs and mean distance at onset of all GEPs. In addition, the absolute duration and distance at onset were quantified for the first GEP on a given pedestrian. Instantaneous walking speed, as well as temporal distance parameters such as step length, step width, and cadence were also examined.

The relative duration of all GEPs per pedestrian was obtained first by identifying pedestrians present in the camera's field of view, which were manually marked with a rectangle for each video frame, as indicated in Figure 3-2. As soon as the point of gaze moved over any pedestrian (rectangle), it would commence a GEP, which lasted as long as the point of gaze was located within that box. Thus, a GEP could have a minimum duration of one timeframe (40 ms) to several time frames. Presence of a blink would result in two successive GEPs. Hence, pedestrians in a particular trial could have one or many recorded GEPs of varying lengths as shown in Figure 3-3. For each pedestrian looked at, the number of GEPs and absolute duration (ms) of all GEPs for that pedestrian were obtained. Then, the total duration of all GEPs per pedestrian was calculated by adding the absolute duration of all GEPs per pedestrian. The relative duration of all GEPs was then obtained by dividing the total duration of all GEPs for a given pedestrian by its total visibility duration in the walking trial, expressed as a percentage. The latter approach allowed to control for differences in the time taken by each participant to walk the pre-set distance and also for the duration for which pedestrians were present in the visual field during the trial.

The distance (m) at onset of GEP was determined by computing the distance between the participant and the bottom of the marking rectangle surrounding the pedestrian, based on the concept of the vanishing point. The latter is a point of intersection or convergence of two mutually parallel lines marked manually on a two-dimensional video plane, which provides a measurement of distance and is based on the method of projective transformation of the plane. More precisely, it is the Pythagorean distance between coplanar points (on the video) transposed to the coordinate system formed by colinear points on the vanishing line (43). The limitation of using this method is that the distance outputted is approximative as a consequence of known and unknown errors. The known error is due to precision loss when marking rectangles around pedestrians as they walk further in the trial scene, thus shrinking in size. The measured error for distances up to 12 meters is estimated at 11.4% (42). The mean distance for a given pedestrian was then calculated by averaging the distance at onset of all its GEPs.

Our focus was also to gain further insight into the visual perception of participants by examining the first GEP vs. all GEPs per pedestrian. Both the absolute duration and distance at onset for the first GEP were noted for a given pedestrian, in order to gain insight into the participant's visual scanning of the environment to locate pedestrians with possible risks of collision, termed herein as *orientation strategy*. At variance, we considered measures of total duration and mean distance of all the GEPs for a given pedestrian as reflecting the ongoing visual monitoring done by participants to update the status of a pedestrian and potential collision risk during the walking trial, which can be referred to as a *monitoring strategy*.

Each gaze behavior outcome described above was further examined in relation to the direction of movement and relative position of pedestrians with respect to the participant. More specifically, direction of pedestrian approach was categorized as *looming* when the pedestrians approached from the direction opposite to the walking direction of the participant and *receding* when the pedestrians walked in the same direction as that of the participant. This classification was done with the prospect of associating risk to the direction of pedestrian approach (e.g., a greater risk of collision is assumed for looming pedestrians). The pedestrians' position with respect to the participant was also estimated using gaze orientation at GEP. The latter was obtained by adding the horizontal eye angle recorded with the Tobii system to the head on trunk angles computed with the APDM system during the GEP, after down-sampling APDM's data at 25Hz to match the sampling frequency of the Tobii system. Based on gaze orientation, obstacles were classified as being located on the left (<-5 deg), center (-5 to 5 deg) and right (>5 deg) visual field of the participant. A central visual field of 10 deg was chosen based on previous literature, as this range is assumed to include foveal and para foveal vision (44, 45). Video images from the scene camera were also scrutinized to identify whether strollers, wheelchairs users, carts, any pedestrian with a walking aid or any pedestrian running were present in the field of view of the participants. Finally, gait speed and temporal distance factors were directly obtained for each trial from the APDM software and computed in MATLAB ® (MathWorks, USA). Average values and coefficients of variation were calculated for each participant while combining all five trials and excluding the beginning and end of trials to exclude acceleration and deceleration phases.

3.3.5. STATISTICAL ANALYSIS

Linear mixed models were used to analyze the outcomes characterizing participants' gaze behavior, including the relative duration of all GEPs, number of GEPs, total duration of all GEPs, mean distance at onset of all GEPs, absolute duration of first GEP and distance at onset of first GEP. To meet the assumptions of a mixed model, the residuals of the parameters had to confine to normality, thus the data was transformed so as to fit the model. Depending on the best fit of normality of the residuals, relative duration of all GEPs, number of GEPs and total duration of all GEPs were square root transformed, while mean distance at onset of all GEPs, distance at onset of first GEP and absolute duration of first GEP were log-transformed. Normality was then confirmed using the Kolmogorov–Smirnov and Shapiro-Wilk tests.

The models comprised of 2 within-subject factors including pedestrian location in the visual field (left, center or right) and the direction of pedestrian approach (looming or receding). Significant main or interaction effects were further elaborated by post-hoc analyses using pairwise t-test comparisons with Bonferroni adjustments. All statistical analyses were performed using SPSS v.24 and the level of significance was set to $p < 0.05$.

3.4. RESULTS

Out of the total of 12 participants, none experienced collisions during the walking trials. No strollers, wheelchair users, carts, people walking with a walking aid or people running were present during the walking trials. There were total of 406 pedestrians looked at by all participants combined across trials. There were only 14 non-obstructive static objects looked at across all trials, which included posters and signs. As those signs were not directly located on the walking path and did not impose a risk of collision for the participant, they were excluded from the analyses. Thus, all the comparisons between the outcomes were carried out while considering pedestrians only.

At the beginning of all trials (first frame), the number of both seen (marked and analyzed) and unseen pedestrians (not looked at throughout the trial) was examined and found to be similar between the left and the right side of participants, as illustrated in Figure 3-4. Despite this equal distribution of pedestrians in the environment, the distribution of pedestrians that were actively gazed at by participants, as identified at onset of GEP, was asymmetrical and skewed towards the right side (Figure 3-5).

Distributions of GEP-related outcomes while considering all GEPs, calculated for all 12 participants are illustrated in Figure 3-6. It can be seen that the distributions roughly follow a gaussian pattern. For the number of GEPs (Figure 3-6A), looming pedestrians appeared to be looked at less frequently and across all gaze angles as compared to receding pedestrians who were looked at more frequently and centrally. Participants also showed a wide range of distances at onset of GEPs, that reached a maximal distance of up to 24m, while maintaining a minimum distance of 2m from the pedestrians (Figure 3-6B). Furthermore, while looming pedestrians seemed to be looked at for a shorter time as compared to receding pedestrians (Figure 3-6C), the relative duration of all GEPs (in percentage) for the two directions of approach was similar (Figure 3-6D).

3.4.1. Group results for all GEPs

Mean values (± 1SD) for the different GEP-related outcomes, while considering all GEPs in the walking trials, are illustrated for looming vs. receding pedestrians for the left, center and right field of vision of participants in Figure 3-7, along with statistically significant comparisons. In terms of the number of GEPs, the mixed model analysis revealed significant main effects of both pedestrian location ($F(2, 54) = 3.97$, $p = 0.025$) and direction of pedestrian approach ($F(1, 54) = 35.68$, $p = 0.00$), as well as an interaction effect of pedestrian direction X location ($F(2, 54) = 3.58$, $p = 0.035$). Post-hoc analysis showed a significantly higher number of GEPs on the receding pedestrians as compared to looming pedestrians for the left ($p = 0.006$) and center ($p = 0.00$) pedestrian locations, but not for the right ($p = 0.063$). In addition, amongst receding pedestrians only, a larger number of GEPs was observed for the center location as compared to left ($p = 0.047$) and right ($p = 0.001$) (Figure 3-7A).

For the mean distance at onset of all GEPs, a significant main effect of pedestrian location ($F(2, 49.23) = 15.67$, $p = 0.00$) was observed, with significantly larger distances being used for pedestrians located in the center (mean difference = 0.140 m, $p = 0.012$) and on the right (mean difference = 0.262 m, $p = 0.00$) compared to the left. No effects of direction of pedestrian approach or interaction effects were observed (Figure 3-7B).

The total duration of all GEPs significantly varied as a function of pedestrian location ($F(2, 44.87) = 3.73$, $p = 0.032$) and direction of approach ($F(1, 43.98) = 30.80$, $p = 0.00$). It also displayed a significant interaction effect of pedestrian location X direction ($F(2, 43.80) = 3.88$, $p = 0.028$). Post-hoc analysis revealed significantly longer total duration of all GEPs on the receding pedestrians as compared to looming for left ($p = 0.006$) and center ($p = 0.00$) pedestrian locations, but not the right ($p = 1.66$). Also, only amongst receding pedestrians, total duration of all GEPs was longer on the center direction as compared to left ($p = 0.041$) and right ($p = 0.006$) directions (Figure 3-7C).

There were no significant effects of direction of pedestrian approach, pedestrian location or interactions effects observed for relative duration of all GEPs (Figure 3-7D).

3.4.2. Group results for first GEP

Separate analyses were also conducted for the first GEPs to gain insight into the participants' initial orientation strategy of visual attention towards the pedestrians present in the environment. As illustrated in Figure 3-8A, distance at onset of the first GEP showed significant main effects of both pedestrian location ($F(2, 51.30) = 11.62$, $p = 0.00$) and direction of pedestrian approach ($F(1, 38.05) = 14.64$, $p = 0.00$). Distances at onset of first GEP were significantly larger for pedestrians located centrally (mean difference = 0.160 m, $p = 0.003$) and on the right side (mean difference = 0.201 m, $p = 0.00$) compared to those located on the left. Pedestrians that were looming were also looked at farther distance compared to those that were receding ($p = 0.00$). There was no interaction effect of pedestrian location X direction on distance at onset of first GEP.

There was a significant main effect of pedestrian location on absolute duration of first GEP ($F(2, 45.46) = 3.94$, $p = 0.027$). Indeed, as in Figure 3-8B, the absolute duration of first GEP of pedestrians located on the right, both looming and receding, was significantly longer than for those located on the left ($p = 0.022$) but showed no difference with those located in the center ($p = 0.704$). No effects of direction of pedestrian approach or interactions effects were observed on absolute duration of first GEP.

3.4.3. Qualitative comparison of outcomes for first GEP vs. all GEPs

The first GEP per pedestrian was assessed for an orientation strategy with absolute duration and distance at onset of first GEP, whereas all GEPs per pedestrian was assessed for a monitoring strategy with total duration and mean distance at the onset of all GEPs. Firstly, the absolute duration of first GEP was greater on the right as compared to left side, while the total duration of all GEPs was greater on the center as compared to right and left sides.

Secondly, for both the first and all GEPs, pedestrians on the right and center were looked at from farther as compared to those on the left side. Lastly, the absolute duration of first GEP on both looming and receding pedestrians was similar but the total duration when considering all GEPs was significantly larger on receding pedestrians. Looming pedestrians were also looked farther than receding at the first GEP, but at an equal distance when considering all GEPs.

Ultimately, we obtained the temporal distance factors (e.g. stride length, step duration, cadence, gait speed) during the evaluation trials across all participants. Table 3-1 displays the mean, SD values and coefficient of variations, which will be further compared to existing data in the literature in the discussion section of the manuscript.

3.5. DISCUSSION

This study is the first, to our knowledge, that used a living lab approach to characterize gaze behavior while ambulating in a community environment and performing complex locomotor tasks, such as avoiding collisions with multiple pedestrians approaching from different directions and locations. While doing so, we also aimed to identify metrics of gaze behavior in a constantly changing environment, as experienced in a real-world setting as opposed to a laboratory setting where experimental conditions are controlled. We suggest that gaze is modulated as a function of the location and direction of pedestrians in the environment and presents with an asymmetrical behavior in space. The analysis of first vs. total GEP may further represent different aspects of the visual scanning strategy during pedestrian avoidance, that is visual orientation and monitoring.

3.5.1. Gaze is modulated as a function of pedestrian direction

Previous evidence from a controlled study with human interferers suggests that individuals modulate their gaze behavior depending on the risk of collision, where the risky interferers, that is those who are on a collision path, are looked at more frequently as compared to the non-risky interferers (16). Similar findings were observed while interacting with risky walkers in a virtual world with joystick-based navigation (9). As for the present study, we can postulate that looming pedestrians, who were moving towards the participant, posed a greater risk of collision compared to receding pedestrians who were moving away, and should have received a prioritization of visual attention. Such postulate, however, is not entirely supported by our findings. First, looming pedestrians were present in the visual field of the participants for lesser time as they passed the participant from the opposite direction, attaining shorter visibility and thus fewer GEPs and durations. Conversely, we found higher numbers of GEPs and longer total duration of all GEPs on receding pedestrians (at least for left and center pedestrian locations), as these were visible to participants for a longer duration. However, a consistent trend for larger relative duration of all GEPs (in percentage) across all locations of pedestrians was observed in the present study for looming vs. receding pedestrian, although this difference did not reach statistical significance. Thus, although looming pedestrians were looked at less often and were present for shorter durations, they bore a visible trend of higher relative duration of GEP, perhaps implying a prioritization for a perceived risk of collision. Second, distances at onset of first GEP revealed that looming pedestrians were looked at from a farther distance as compared to the receding pedestrians. This larger distance can be justified as an attempt to acquire visual information and plan collision avoidance at an earlier time or from a further distance, although that would need to be confirmed experimentally through the measurement of onset time/distance of avoidance strategy. It should be noted, however, that this difference in distance at onset of GEP vanished when considering all GEPs across the walking trials. In fact, a minimum distance of about 2 meters from the pedestrians was recorded regardless of pedestrian direction or location, possibly due to one's perceived personal space (25). In a study on gaze behavior while stepping over an obstacle, Patla and Vickers (1997) showed that the obstacle was looked at 1 to 2 steps prior to stepping over the obstacle, but not during the actual obstacle avoidance (46). Similarly, in the present study, this minimal distance of 2m might have been implemented to allow sufficient time and distance to control, in a feedforward manner, a successful circumvention strategy.

3.5.2. Modulation as a function of pedestrian location

The distribution of all GEPs as a function of *gaze orientation* measured at their onset revealed a rightward bias, despite of an equal distribution of pedestrians present in the right vs. left visual field of participants. While this rightward bias subsided for most GEP outcomes when considering all GEPs as a function of *mean gaze orientation*, it remained present for the first GEP for which farther distances and longer durations were observed for right-located pedestrians vs. those located in the center and/or left. Past research has shown that the collision avoidance strategy established between two pedestrians is the result of a mutual 'negotiation' amongst them, where each adapt their path to avoid each other (4, 24) or where one leads the avoidance (47). Collision avoidance strategies also are influenced by cultural factors, such as the country's traffic rule. In North America, for instance, car circulation obey a right-side traffic rule, which also translates by having pedestrians adopting primarily right-sided collision avoidance strategies (5, 25). In the present study, it is possible that individuals used a visual orientation strategy that involves scanning more often, for a longer duration and at a farther distance those pedestrians that were on the right side, for the purpose of planning for a future travel path that complies with the right-side traffic rule and which is collision free. The observation of a rightward bias in gaze behavior in the present study also apparently contrasts with another body of literature on visual discrimination tasks, which instead demonstrated the presence of a leftward bias (48-50). In a context of a lower level of alertness, however, this bias was shown to be shifted to the right (51, 52). We argue that collision avoidance in a mall, at least for healthy young individuals, may not require a level of alertness as high as for visual discrimination tasks, where an active discrimination process and overt response are required.

Another factor that could also explain the rightward bias in GEP distribution is the right handedness of individuals in this study (53). Observations from Gérin-Lajoie et. al (2008) showed that right-handedness yields smaller right personal spaces from obstacle during leftward circumventions (25). They suggested that since personal space serves the purpose of perceiving, planning and reacting to hazards in the environment, its smaller size was consistent with the faster processing speed of visuospatial information on the right/dominant side. A shifted distribution of gaze episodes towards the right space, as observed in the present study which exclusively included right-handed individuals, may actually contribute to some extent, to an enhanced processing of visuospatial information on the right/dominant side.

As the receding pedestrians were followed through the trials and were present for longer in the visual field of the participants, they had the greatest number of GEPs along with the longest total duration of all GEPs, amongst those centrally located (Figure 3.7A, C). It was thought that the centrally located, looming pedestrians would bear increased GEPs and duration due to the fact that those were potentially head-on approaches, thought to impose a perceived risk of collision. However, this wasn't particularly observed in this case. Instead, it appears that the longer visibility of receding pedestrians, especially those located in the center thus in the projection of participant's walking trajectory, caused longer durations of GEP. In return, longer durations of GEP made it possible to monitor the displacement of these pedestrians while following them.

3.5.3. Temporal distance factors

Lastly, there was an increased variability of the temporal distance factors measured by the APDM system in this study than that of other studies that used the same equipment in a laboratory setting (54-57). This could be explained by the controlled nature of the studies executed in the laboratory setting where most of the variables are being accounted for, whereas that in our study could not be controlled, considering its nature. Hence, participants made global adjustments to the environmental challenges, in addition to the local adjustments to stimuli present in the environment.

3.5.4. Limitations

Limitations include the lack of quantification of gaze on the environmental aspects of the evaluation setting, for e.g. the floor, ceiling, shops, etc. Also, its generalizability to other populations groups, especially those seen in a rehabilitation setting who are not only older but also present with sensorimotor impairments. Other limitations include the lack of control on the environment – crowd density and characteristics of pedestrians (gender, race, age, speed, direction, etc.). We believe however that participants employed similar obstacle avoidance strategy amongst this diversity, enabling us to extract fundamental features of gaze behavior that remained common across obstacle circumvention situations, and which can be used as metrics to characterize gaze behavior in a community setting such as a shopping mall. And this would then serve as measures for comparison with other population groups presenting visuomotor control impairments and reduced community ambulation abilities such as older adults and individuals with physical disability (e.g. stroke).

3.6. CONCLUSION

In the context of this study, there was an effort to propose an innovative research project that allowed investigating gaze behavior from a visuomotor perspective, in a complex, community environment such as the mall. The results showed that healthy young adults exhibit modulations in their gaze behavior as a function of pedestrian location and approaching direction in the mall. Indeed, while the rightward bias of GEP distribution observed in this study appears to reflect a rightward bias in visuospatial attention, gaze allocation on pedestrians remained modulated by factors such as the perceived risk of collision and the total visibility (both in terms of duration and location) of pedestrians in the observer's field of view. Results of this study furthers the understanding of gaze behavior during community ambulation, while establishing a benchmark for the quantification of defective visuomotor strategies in those individuals with mobility disorders.

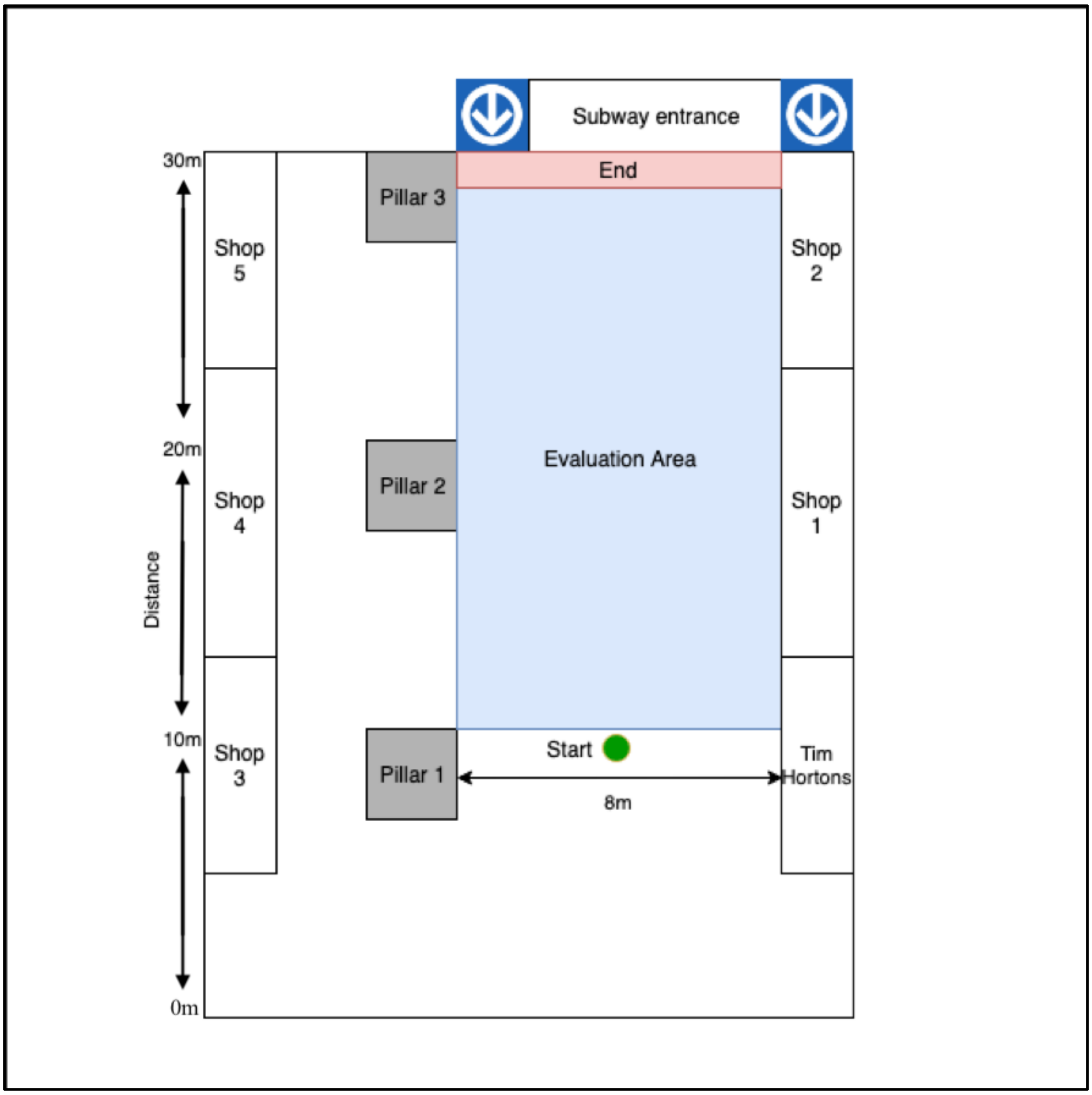

Figure 3-1. Bird's eye view of the evaluation setting in the mall.

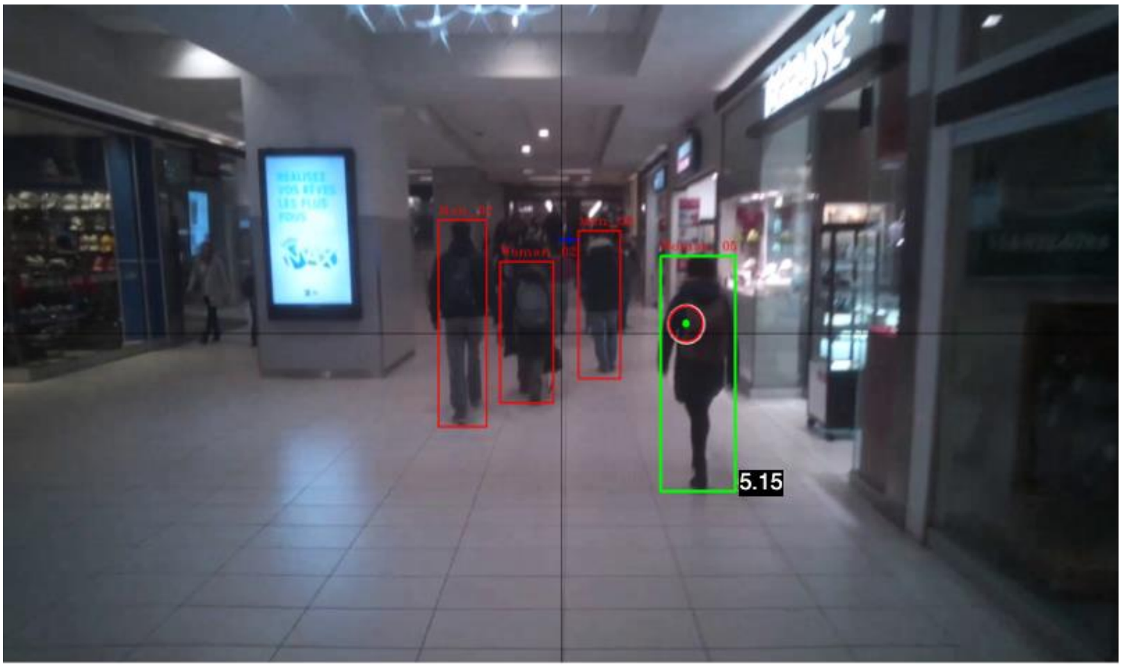

Figure 3-2. Representation of one of the video frames from a walking trial. Pedestrians present in the hallway were labeled offline for every video frame using boxes. A given box turns green when the point of gaze moves over the region defined by its contour, and otherwise remains red. The number next to the green box (5.15) represents the distance at onset of gaze episode on pedestrian (GEP).

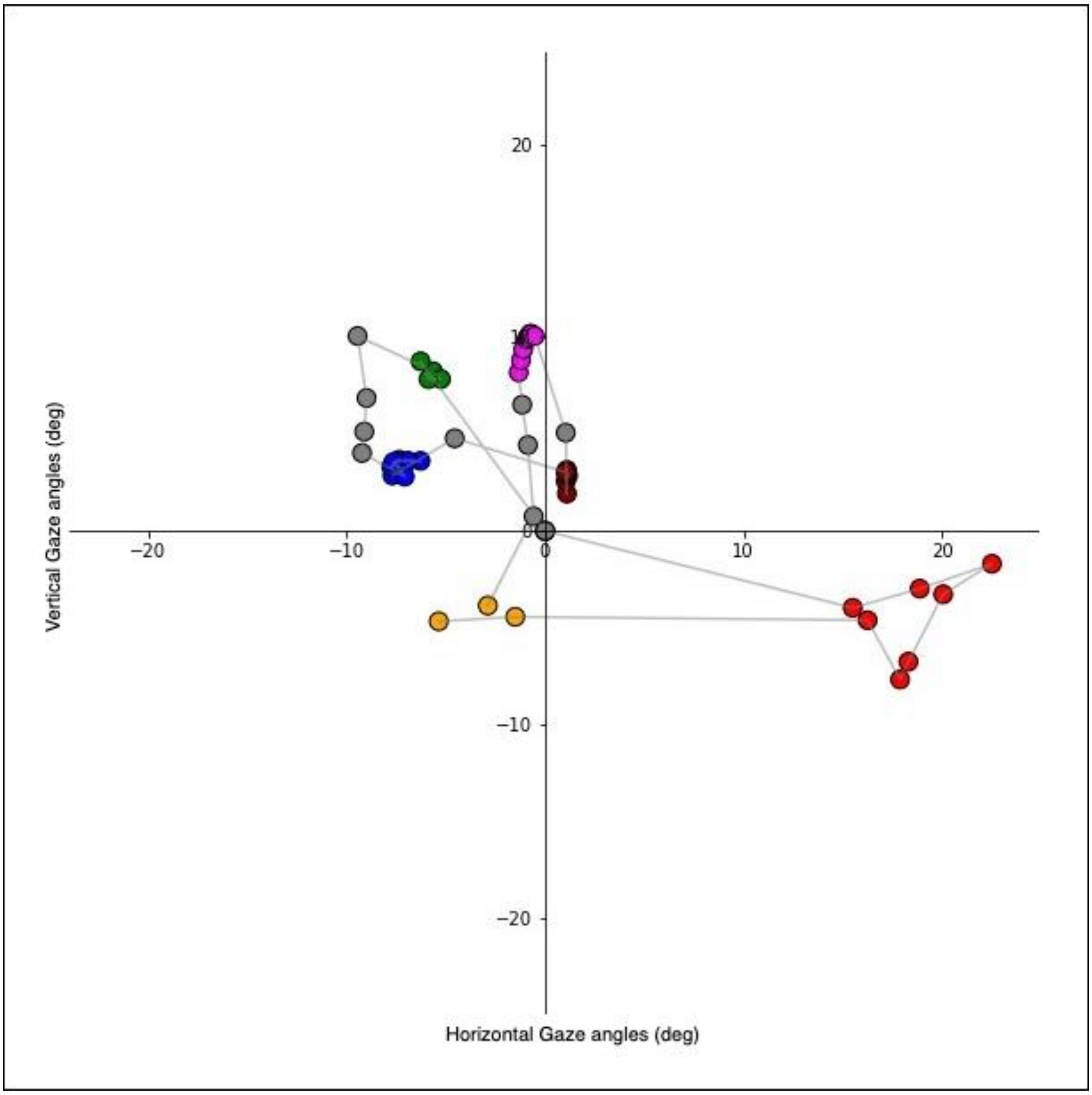

Figure 3-3. Two-dimensional graph of the shifts in the point of gaze of a participant, for 2000 ms during a walking trial. Each point (grey and colored) represents a GEP, while the clusters are colored to illustrate all the GEPs for a given pedestrian.

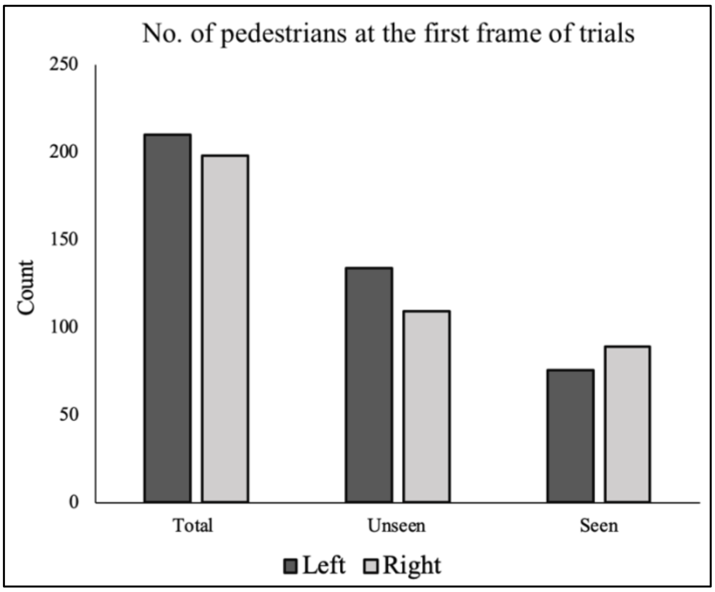

Figure 3-4. Number of pedestrians, seen and unseen, that were present in the visual field of all participants across all trials. Note the equal distribution of pedestrians present on the right and the left visual fields of the participants.

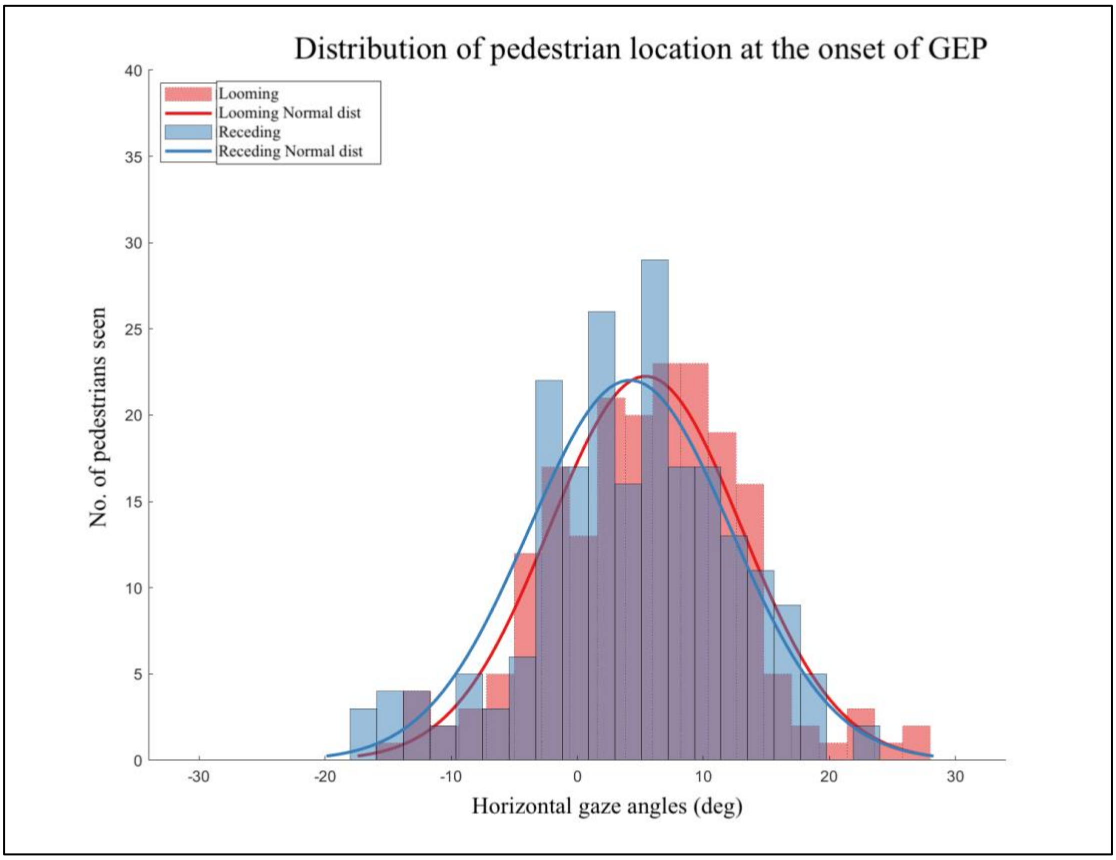

Figure 3-5. Distribution of pedestrians across the horizontal gaze angles at the onset of first GEPs, that is when they were first looked at. Note the normal distribution curve with a rightward skew for both the looming and receding pedestrians, which indicates that a larger number of GEP were observed on the right vs. left visual field.

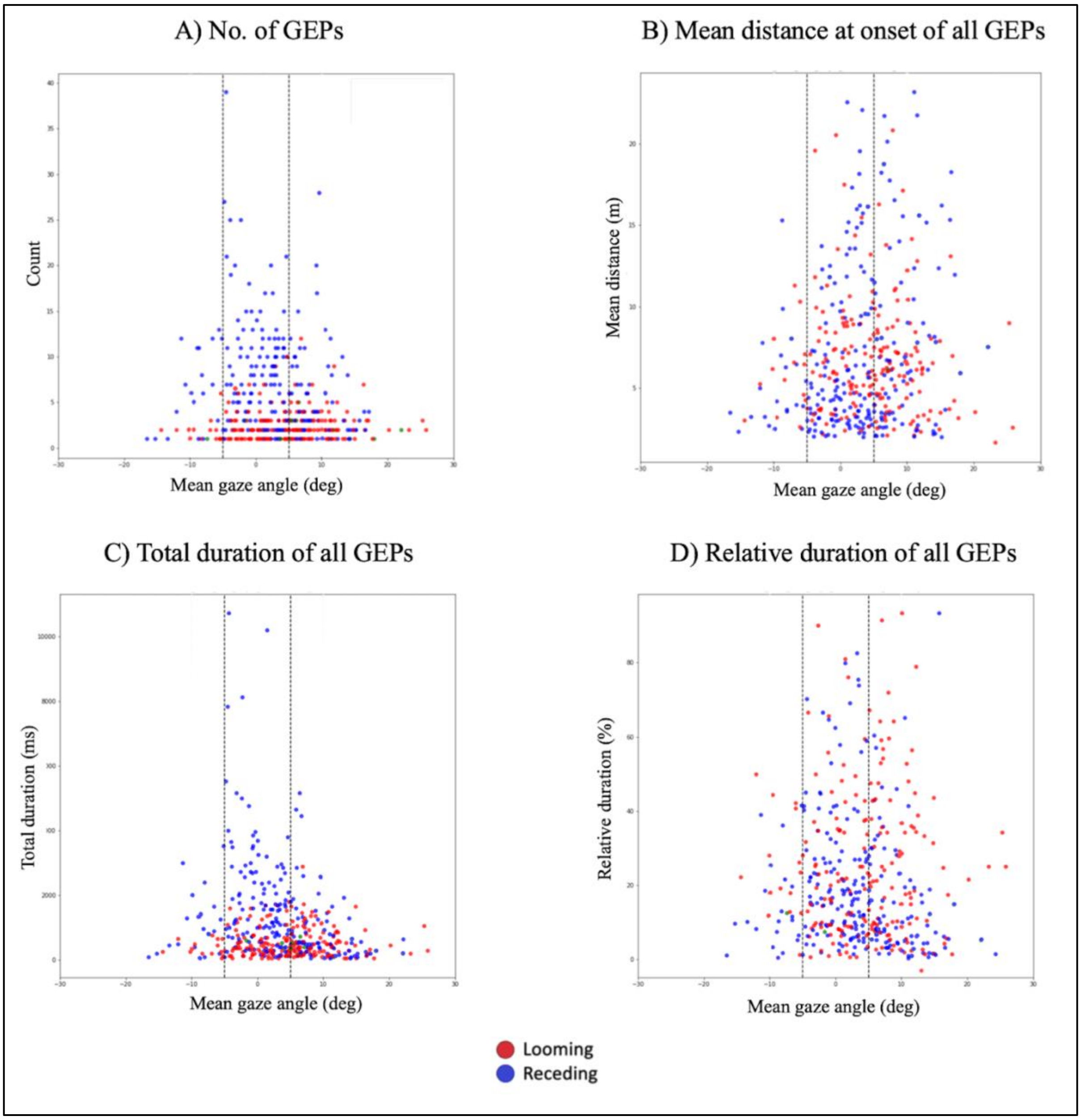

Figure 3-6. Scatter plots where all 406 pedestrians are plotted across all 12 participants depicting the number of GEPs (A), mean distance at onset of all GEPs (B), total duration of all GEPs (C) and relative duration of all GEPs (D) as a function of horizontal gaze angle. The two vertical lines represent the ±5° boundaries delimiting the central visual field.

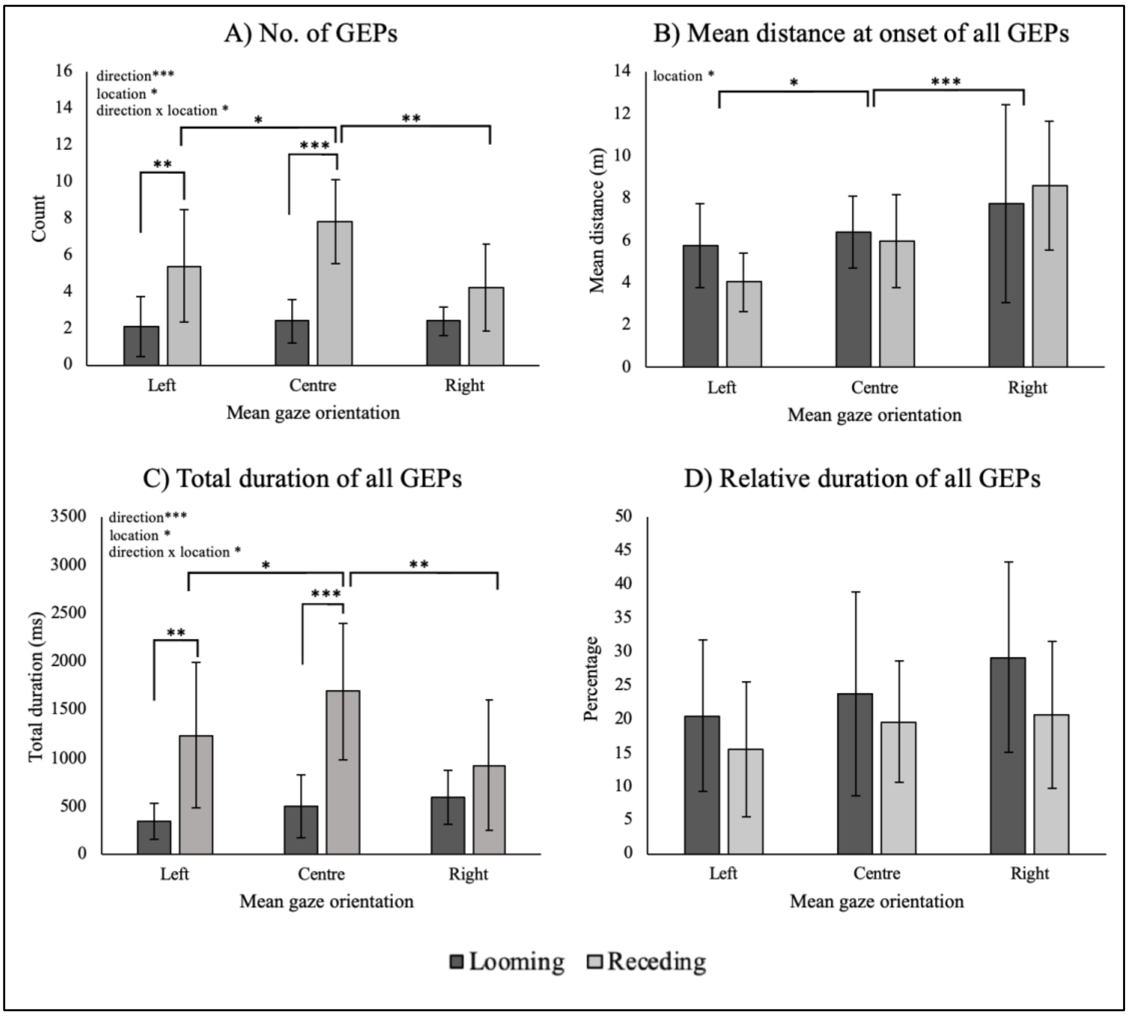

Figure 3-7. Group mean ± 1SD values for the number of GEPs (A), mean distance at onset of all GEPs (B), relative duration of all GEPs (C) and total duration of all GEPs (D). Values are represented separately for looming vs. receding pedestrians, as well as for the left, center and right visual fields. Statistically significant main and interaction effects are indicated, as applicable. Likewise, post- hoc comparisons that were statistically significant are also illustrated. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$

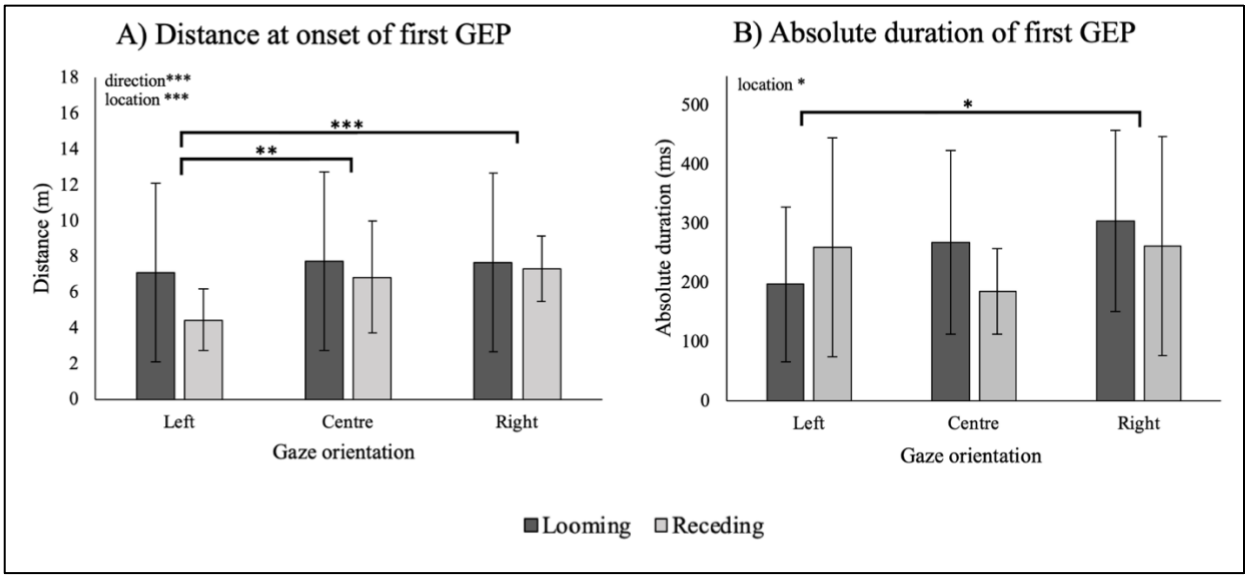

Figure 3-8. Group mean ± 1SD values for distance at onset of first GEP (A) and absolute duration of first GEP (B). Statistically significant main effects are indicated, as applicable. Likewise, post- hoc comparisons that were statistically significant are also illustrated. * p < 0.05. ** p < 0.01. *** p < 0.001

Table 3-1. Mean, standard deviation (SD) and coefficient of variation for temporal distance factors. Values were calculated for each participant, before being averaged across all 12 participants.

Temporal distance factors	Mean	SD	Coefficient of variation
Stride length (m)	1.36	0.12	8.60
Step duration (s)	0.51	0.03	5.83
Cadence (steps/min)	118.71	6.45	5.44
Gait speed (m/s)	1.33	0.19	14.03

CHAPTER 4: GENERAL DISCUSSION

In this study, we examined gaze behavior as healthy individuals ambulated and avoided other pedestrians in a living lab environment. It would be the first in the literature to develop and evaluate metrics for characterizing gaze behavior in a healthy young population during a complex walking task in a real-world setting. We examined if, despite the complexity of a community environment, healthy young adults did actually exhibit stereotyped gaze behavior possibly modulated as a function of obstacle characteristics. Explanations for these findings and implications are discussed below.

4.1. GAZE MODULATED AS A FUNCTION OF PEDESTRIAN DIRECTION

There is evidence suggesting that participants modulate their gaze to the relevant tasks and aspects in the environment associated to risk (9, 16, 23), and our findings confirm these previous investigations. To examine risk associated to the direction of pedestrian approach, a higher risk was thought to be deduced from the looming pedestrians as they intrinsically had more probability of collisions as compared to receding pedestrians. Results, however, showed that receding pedestrians were looked at more often and for longer as compared to looming pedestrians, as receding pedestrians were followed by the participants through most of the length of trials. However, a trend in relative duration was noted, for looming vs. receding pedestrian, which signifies that looming pedestrians were looked at proportionally longer during their brief visibility in trials, while receding pedestrians being present in most of the trial's length weren't looked at as much, implying prioritization of perceived risk of collision.

Another difference in the distance at onset of first GEP was that the looming pedestrians were looked farther as compared to the receding pedestrians, perhaps as an attempt to foresee a risk of collision and identifying them at a distance. However, this difference disappeared when considering all GEPs across the walking trials. Besides, a minimum distance of about 2 meters was observed from the pedestrians at the first GEP possibly to maintain a safety margin or to prepare for an avoidance strategy.

4.2. MODULATION AS A FUNCTION OF PEDESTRIAN LOCATION

Regardless of an equal number of pedestrians on left vs. right side of participants, the distribution of all GEPs at onset, was skewed towards the right side. This bias diminished for most outcomes during all GEPs, but it remained present for farther distances and longer durations being observed for pedestrians in the right vs. center and/or left. The same was probably influenced by the right-side traffic rule of North America, having pedestrians adopting primarily right-sided collision avoidance strategies (5, 25). Individuals perhaps used a visual orientation strategy by scanning more often and longer at a farther distance on pedestrians on the right side, for the purpose of planning a collision free travel path conforming to the right-side traffic rule. This although contrasts with most of the literature on visual discrimination tasks which demonstrate a leftward bias (48-50). It could also be linked to the dominance of individuals in this study (52, 53, 58), alertness (51, 52) and handedness (25, 53)

The receding pedestrians located in the central visual field of the participants were looked longer and more often. Initially it was believed that the centrally located looming pedestrians, which are potentially head-on approaches would have imposed a perceived risk of collision and would receive more and longer GEPs. This, however, wasn't particularly observed here.

4.3. ORIENTATION V/S. MONITORING STRATEGY?

The first GEP per pedestrian was assessed for an orientation strategy, whereas all GEPs were examined for a monitoring strategy. The length of the first GEP on both looming and receding pedestrians was similar, while that of all GEPs was significantly larger for receding pedestrians. It shows that an equal amount of time was utilized at the first GEP to identify the pedestrians to plan an avoidance strategy, and then trail behind receding pedestrians. Also, at the onset of first GEP, looming pedestrians were looked at from farther as compared to receding pedestrians, suggesting the implementation of an orientation strategy from a distance. Then for all GEPs, both the pedestrian approaches were looked at from an equal distance, maybe as farther monitoring was redundant once pedestrians had already been scanned.

The pedestrians on the right as compared to left side were looked at longer during the first GEP, while for all GEPs, duration was longer at center as compared to right and left sides. This indicates that both the pedestrians were scanned first on the right side, perhaps to account for the traffic rule to locate and plan collision avoidance strategy. Probably just as looming pedestrians were avoided, the GEPs moved towards the center to monitor the status of collision avoidance on the receding pedestrians which were being followed.

4.4. TEMPORAL DISTANCE FACTORS

An increased variability was observed, comparing the coefficient of variation of gait speed, stride length, step duration and cadence measured by the APDM system in this study to values obtained in other studies that used the same equipment in a laboratory setting (54-57). This is probably explained by the nature of the studies being compared, from studies in laboratories with controlled variables to an evaluation setting which could not be controlled. The temporal distance factors provided an additional overview of human locomotor adaptations in response to real-life varying obstacles, when compared to those in environments which were controlled. It implies that participants made global adjustments to the environmental challenges, in addition to the local adjustments to stimuli present in the environment.

4.5. LIMITATIONS

This study has some limitations which include the lack of quantification of gaze behavior on the environmental aspects of the evaluation setting, for e.g. the floor, ceiling, shops around. Nevertheless, advancements in the software used for detecting the objects of interest in video data could provide additional data to run such analyses. Also, a convenience sample of right-handed, healthy young participants between the ages of 18 – 29 years of age were included in this study. As this population may not represent the population at large, especially those seen in a rehabilitation setting who are not only older but also present with sensorimotor impairments, it limits the generalizability of results to the general population. Other limitations include the lack of control on the environment – number and characteristics of pedestrians (gender, race, age, speed, direction, etc.). We believe though, that such diversity will enable us to extract fundamental features of gaze behavior that remain common across obstacle circumvention situations, and which can be used as robust metrics to eventually identify pathological circumvention strategies.

4.6. FUTURE DIRECTIONS IN REHABILITATION

This study offers a wide scope by being the first to provide metrics to quantify gaze behavior during a complex walking task in a community environment. Having young participants gives a benefit of understanding gaze behavior in the absence of other limiting factors such as older age or a pathology affecting gait. Now, there is an availability of this information that can form the basis of comparison for future studies. Thus, it leads us to a prospect of applying the metrics from this population of healthy young adults and configure it to different population groups, for e.g. elder adults, patients with mobility impairments (e.g., stroke) or those with visuo-perceptual impartments (e.g., stroke with unilateral spatial neglect), which can provide us with an insightful picture of the varied alterations in gaze amongst those specific population groups.

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APPENDICES

APPENDIX 1 – English Consent form

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We are asking you to participate in a research project involving the evaluation of walking or wheelchair navigation abilities in a shopping mall. Before agreeing to participate in this project, please take the time to read and carefully consider the following information.

This consent form explains the aim of this study, the procedures, advantages, risks and inconvenience as well as the persons to contact, if necessary.

This consent form may contain words that you do not understand. We invite you to ask any question that you deem useful to the researcher and the other members of the staff assigned to the research project and ask them to explain any word or information which is not clear to you.

Introduction:

Vision plays an important role in the control of walking and wheelchair navigation. It allows us to move in the desired direction and avoid potential hazards on our path. With the occurrence of a cerebrovascular accident (CVA), the ability to move and to use the sense of vision can be altered. It may become especially challenging to move in a 'busy' environment such as a shopping mall, which includes both static (columns, benches) and moving obstacles (other persons walking) that need to be avoided. In the context of this project, we are investigating how persons with a CVA, compared to persons without a CVA, control their gaze and their walking or wheelchair trajectory in a shopping mall.

Objectives:

1. To develop measures that allow to characterize steering and obstacle avoidance strategies while walking or while using a wheelchair in the mall;

2. To characterize gaze behaviours and displacement strategies in stroke participants with and without visual field loss and visuo-spatial neglect (hemineglect).

Nature of my participation:

My participation will consist of two sessions of 1.5 hour to 2 hours each.

First session will consist of an assessment of my handedness using Edinburgh handedness inventory and the visual acuity by EDTRS chart, followed by an evaluation of my gaze behaviour and displacement in the shopping mall *Place Alexis-Nihon*, in Montreal. In the following paragraphs, the procedures to get to the mall, the preparation needed before the experiment and the actual evaluation are described.

Second session will comprise only of the evaluation of my gaze behaviour and displacement in the shopping mall *Place Alexis- Nihon,* in Montreal.

Getting to the mall: In order to get to the mall, I shall take adapted transportation services, a taxi, or get to the mall by other means (e.g. by car), as agreed in advance with a member of the research team involved in this project. A resource person and one of the researchers will be present to greet me and give me assistance upon arrival.

Preparation: Once I get to the mall, a member of the team will guide me to a quiet room. I will be fitted with special eyeglasses that allow recording the movements of my eyes. Sensors will also be attached to my waist, foot and walking aid (if any) to record my movements as I walk. The eyeglasses and sensors are light and should not restraint my movements or cause discomfort. Altogether, this preparation will last **30 minutes**.

Evaluation of walking or wheelchair displacement: Starting from a central location on the main floor, I will be asked to go several times to different stores (e.g. florist, natural product store, dollar store). All stores are located nearby, on the same floor. A member of the team will help me locate each store and visit the area prior to the data collection. Depending on my endurance, I shall walk or use my wheelchair to go 2 to 3 times to each store. I will be videotaped as I walk to the different stores. A member of the team will always stay near me and I shall rest as often as needed throughout the evaluation. This evaluation will take a **maximum of 1 hour.**

Risks and disadvantages:

Risks associated to my participation in this study are minimal. During my walking evaluation, a member of the team will always be present to provide any assistance and to prevent me from falling. I may, however, feel tired following the evaluation. The feeling of fatigue will wear off with rest. Transportation time to the Alexis-Nihon Mall may also vary, depending on the starting location and traffic.

Benefits:

This study does not provide me any direct benefit. However, the results from this study will provide information that will help in better understanding the difficulties faced by persons with a CVA when walking in a challenging environment such as a mall.

Financial compensation:

Transportation and parking costs incurred through my participation in this project will be reimbursed, up to a maximum of $30.00 per visit.

Access to my medical chart:

If I had a CVA, I understand that some relevant information concerning my medical history may need to be collected, and for that purpose, a member of the researcher team may need to consult my medical file. Only the sections pertaining to my CVA, however, will be consulted.

Confidentiality:

Any personal information making it possible to identify me is kept confidential and will be filed in a locked cabinet. The data relating to my evaluations will be transferred onto a computer file server where access is protected by passwords. Only members of the research team have access to the information collected during the project. If I withdrew my participation from this project, all the research data collected would be destroyed. Otherwise, the information will be preserved for a duration of 5 years, after which they will be destroyed. The data of this research will only be revealed in the form of scientific presentations or publications, without my name or identity exposed. For monitoring purposes, research documents could be accessed by a representative of the Research Ethics Board of CRIR or of the Ethics Unit of the Ministry of Health and Social Services of Quebec, which adhere to a strict privacy policy.

CONSENT: I can be assured that the information that I have received about this project is accurate and complete. My participation in this project is entirely voluntary. My refusal to participate would in no way affect the treatment I receive in this hospital. In addition, I may withdraw from the study at any time.

Should I have any questions or require further information regarding the study, I can contact Dr. Anouk Lamontagne at the Jewish Rehabilitation Hospital (phone number 450-688-9550 ext. 531; e-mail anouk.lamontagne@mcgill.ca). If I have any questions regarding my rights and recourse concerning my participation in this study, I can contact Ms. Anik Nolet, Research Ethics Co-ordinator of the CRIR establishments: 514-527-4527 ext 2643 or by e-mail at: anolet.crir@ssss.gouv.qc.ca

In accepting to participate in this study, I shall not relinquish any of my rights and I shall not liberate the researchers or their sponsors or the institutions involved from any of their legal or professional obligations.

My signature indicates that I have read this document, that I understand the purpose of the research, that this project will not be of direct benefit to me, and that I agree to participate. A copy of this form will be provided to me for my record.

Subject: ____________________________________ Date: ___________________ _______

(Signature)

____ on the: ___________________ _______

(Name)

Responsibility of the principal investigator:

I, the undersigned, ________________________________ certify that (a) I have explained to the participant the terms of the present agreement, (b) I have responded to all questions posed to me, and (c) I have clearly indicated that the participant is free to leave the study described above at any time, and (d) I have provided a signed and dated copy of this consent document to the participant.

Signature of the principal investigator or his/her representative
Signed in _________________________ on the______________________

APPENDIX 2 - French consent form

Chercheure responsable du projet:
Anouk Lamontagne, Ph.D., PT
Hôpital Juif de réadaptation (HJR)
École de physiothérapie et d'ergothérapie, McGill University

Chercheurs collaborateurs:
Philippe Archambault, OT, Ph.D.
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Eva Kehayia, PhD
École de physiothérapie et d'ergothérapie, McGill University
Hôpital Juif de réadaptation (HJR)

Nous vous invitons à participer à un projet de recherche effectué par des chercheurs de l'Hôpital Juif de réadaptation (HJR) et de l'Institut Nazareth et Louis-Braille (INLB) concernant l'évaluation de vos capacités à vous déplacer à pied ou en chaise roulante dans un centre commercial. Avant d'accepter de participer à ce projet de recherche, veuillez prendre le temps de comprendre et de considérer attentivement les renseignements qui suivent.

Ce formulaire de consentement vous explique le but de cette étude, les procédures, les avantages, les risques et inconvénients, de même que les personnes avec qui communiquer au besoin.

Ce présent formulaire peut contenir des mots que vous ne comprenez pas. Nous vous invitons à poser toutes les questions que vous jugerez utiles au chercheur et aux autres membres du personnel impliqués dans le projet de recherche et à leur demander de vous expliquer tout mot ou renseignement qui n'est pas clair.

Préambule:

La vision joue un rôle important dans le contrôle de la marche et des déplacements en fauteuil roulant. Elle nous permet de nous déplacer dans la direction souhaitée tout en évitant les dangers potentiels sur notre chemin. Avec la survenance d'un accident vasculaire cérébral (AVC), la capacité à se déplacer et à utiliser la vision peut être altérée. Il peut devenir particulièrement difficile de se déplacer dans un environnement animé comme un centre commercial, qui comprend à la fois des obstacles statiques (colonnes, bancs) et mobiles (d'autres personnes en déplacement) à éviter. Dans le cadre de ce projet, nous étudions la façon dont les personnes ayant un AVC, avec ou sans pertes visuelles, contrôlent leur regard et leur trajectoire lorsqu'elles marchent ou se déplacent en chaise roulante dans un centre commercial, comparé aux personnes qui n'ont pas eu d'AVC.

Description des objectifs du projet:

3. Élaborer des mesures permettant de caractériser les stratégies de contrôle de direction et d'évitement d'obstacles lors de la marche ou lors du déplacement en chaise roulante dans le centre commercial;

4. Caractériser les comportements du regard et les stratégies de déplacement des personnes ayant un AVC avec et sans perte du champ visuel ou négligence spatiale unilatérale (héminégligence).

Nature et durée de ma participation:

Mon implication personnelle dans ce projet de recherche consistera à participer à deux activités d'une heure et demi à deux heures chacune.

La première session consistera en une évaluation de ma préférence manuelle par le questionnaire de latéralité manuelle d'Edinburgh et de mon acuité visuelle par l'échelle ETDRS. Ces tests seront suivis par une évaluation de mes déplacements et de mes comportements visuels dans le centre commercial Place Alexis-Nihon à Montréal. Les paragraphes suivants décrivent les procédures pour se rendre au centre commercial, la préparation nécessaire avant l'expérimentation et les procédures d'évaluation.

La seconde session sera seulement une évaluation de mes déplacements et de mes comportements visuels dans le centre commercial Place Alexis-Nihon, à Montréal.

Se rendre au centre commercial: Afin de me rendre au centre commercial, je prendrai le service de transport adapté, un taxi ou un autre moyen (par exemple en voiture), comme convenu à l'avance avec un membre de l'équipe de recherche. Une personne-ressource et l'un des chercheurs seront présents pour m'accueillir et me donner assistance à l'arrivée.

Préparation: Une fois au centre commercial, un membre de l'équipe m'accompagnera à un local tranquille. Je serai équipé de lunettes spéciales qui permettent d'enregistrer les mouvements des yeux. Des capteurs seront également attachés à ma taille, à mes pieds et, le cas échéant, à mon aide à la mobilité pour enregistrer mes mouvements pendant que je me déplace. Les lunettes et les capteurs sont légers et ne devraient pas limiter mes mouvements ou causer de l'inconfort. Au total, cette préparation durera **30 minutes.**

L'évaluation de mes déplacements à pied ou en chaise roulante: À partir d'un point central, à l'étage principal du centre commercial, je vais être invité à me déplacer plusieurs fois vers différents magasins (par exemple, fleuriste, boutique de produits naturels, magasin à un dollar). Tous les magasins sont situés à proximité, sur le même étage. Un membre de l'équipe m'aidera à localiser chaque magasin et me fera visiter les locaux avant la collecte des données. Selon mon endurance, je me déplacerai à pied ou en chaise roulante 2 à 3 fois jusqu'à chacun des 3 magasins. Je serai filmé pendant que je me déplace vers les différents magasins. Un membre de l'équipe restera toujours près de moi et je pourrai me reposer aussi souvent que nécessaire tout au long de l'évaluation. Cette évaluation prendra un maximum de **1 heure**.

Risques pouvant découler de votre participation :

Ma participation à ce projet de recherche ne me fait courir, sur le plan médical, aucun risque que ce soit. Lors de l'évaluation de mes déplacements, un membre de l'équipe sera toujours présent pour fournir toute l'aide et pour m'empêcher de tomber. Je pourrais ressentir une fatigue suite à l'évaluation. Cependant, cela va s'estomper avec le repos. Le temps de transport au centre commercial l'Alexis-Nihon peut également varier en fonction du lieu de départ et du trafic.

Avantages pouvant découler de votre participation:

Cette étude ne m'apportera pas de bénéfice direct. Cependant, les résultats de cette étude (aideront les chercheurs) à mieux comprendre les difficultés rencontrées par les personnes ayant subi un AVC lors des déplacements à pied ou en chaise roulante dans un environnement difficile comme un centre commercial.

Indemnité compensatoire:
Les frais de transport et de stationnement occasionnés par ma participation à ce projet seront remboursés jusqu'à un maximum de 30,00 $ par visite.

Accès à mon dossier médical:

Si j'ai subi un AVC, je comprends que certains renseignements pertinents concernant mes antécédents médicaux peuvent être collectés, et à cette fin, un membre de l'équipe de recherche peut avoir besoin de consulter mon dossier médical. Cependant, seules les sections se rapportant à mon AVC seront consultées.

Confidentialité des données:

Tous les renseignements personnels recueillis à mon sujet au cours de l'étude seront tenus confidentiels et conservés dans une filière sous clé. Les données relatives à mes évaluations seront transférées à un serveur informatique dont l'accès est protégé par des mots de passe. Seuls les membres de l'équipe de recherche ont accès à l'information collectée durant le projet. Si je décide de retirer ma participation à l'étude, toutes les informations me concernant seront détruites. De plus, ces informations seront conservées pour une durée de 5 ans, après quoi elles seront détruites. En cas de présentation de résultats de cette recherche ou de publication, rien ne pourra permettre de m'identifier. À des fins de contrôle du projet de recherche, votre dossier de recherche pourrait être consulté par une personne mandatée par le Comité d'éthique (CÉR) des établissements du CRIR ou par l'Unité de l'éthique du ministère de la Santé et des Services sociaux du Québec, lesquels adhèrent à une politique de stricte confidentialité.

Consentement:
Je peux être assuré que les informations que j'ai reçues sur ce projet sont exactes et complètes. Ma participation au projet de recherche décrit ci-dessus est tout à fait libre et volontaire. Il est entendu que je peux, à tout moment, mettre un terme à ma participation sans que cela n'affecte les services de réadaptation que je reçois de l'INLB ou de l'HJR.

Si j'ai des questions sur mes droits ou besoin d'information additionnelle concernant cette étude, je peux communiquer avec Anouk Lamontagne à l'Hopital Juif de réadaptation (téléphone 450-688-9550 poste 531; courriel anouk.lamontagne@mcgill.ca) Si vous avez des questions sur vos droits et recours ou sur votre participation à ce projet de recherche, vous pouvez communiquer avec Me Anik Nolet, coordonnatrice à l'éthique de la recherche des établissements du CRIR au (514) 527-4527 poste 2649 ou par courriel à l'adresse suivante : anolet.crir@ssss.gouv.qc.ca

En acceptant de participer à cette étude, je ne renoncerai à aucun de mes droits et je ne libérerai pas les chercheurs, leurs commanditaires ou les institutions concernées, de leurs obligations légales ou professionnelles.

Je confirme que j'ai lu ce document, que je comprends le but de la recherche, que ce projet ne sera pas un avantage direct pour moi, et que je suis d'accord pour participer.

Une copie signée de ce formulaire d'information et de consentement doit m'être remise.

NOM DU PARTICIPANT	SIGNATURE
______________________________	__________________________________

Fait à _______________________ le ______________________

Engagement du chercheur ou du coordonnateur de recherche

Je, soussigné(e), ________________________________, certifie

a) avoir expliqué au signataire les termes du présent formulaire;
b) avoir répondu aux questions qu'il m'a posées à cet égard;
c) lui avoir clairement indiqué qu'il reste, à tout moment, libre de mettre un terme à sa participation au projet de recherche décrit ci-dessus;
d) que je lui remettrai une copie signée et datée du présent formulaire.

____
Signature du responsable du projet
ou de son représentant

Fait à _____________________, le ___________________