Specific Aims

Vision provides crucial information for successfully moving through the environments of daily life. There is a rich and growing body of literature that describes vision and visual perception in response to dynamic and realistic environments [CITE], as well as the details of the biomechanics of walking in natural environments [CITE]. However, the vast majority of experiments investigating the sensorimotor processes underpinning the visually-guided walking are conducted in isolation, focusing primarily on visual perception or motor function [CITE]. As a result, there is a lack of data to support the development of a normative description of the sensorimotor processes involved in walking. This significantly hinders the development of models of the cognitive planning and visual information gathering processes that integrate the details of visual processing AND the bimoechanics of human movement. Understanding these basic sensorimotor processes is critical to human health as we age, as there is considerable evidence that visual impairment and other changes associated with aging put individuals at a high risk for falls.

The overarching goal of this proposal is to **develop an integrated model of the visuomotor processes that support movement through real-world environments**. It will provide a detailed and integrated account of the visual information gathering and cognitive/motor planning processes that support walking. We will take into consideration the role of divided attention and the way that it shapes the coordination of gaze and gait by limiting visual information gathering and cognitive processing. This work will be informed by the collection of an **integrated visuomotor dataset (eye tracking and full-body movement through real-world environments)** and a series of controlled-laboratory experiments with protocols designed to mimic the visually-guided walking observed in the natural environment. These complementary approaches will enable the observation of real-world behavior, while still providing precise laboratory measurements to test specific hypotheses related to the **dynamics of visual information-gathering and motor planning**.

We are uniquely positioned tackle this set of scientific questions, having developed both environment- and laboratory-based data collection techniques that produce integrated visuomotor datasets for full-body movement. The fields of vision science, neuroscience, and biomechanics are at a critical junction as advances in machine learning increase the capacity for processing and analyzing big multi-modal data. However, the success of such efforts is dependent on the content and quality of the data that exist. Our proposed work will result in a high-quality, open-source, visuomotor dataset. Furthermore, each aim includes planned technical deliverables. These open-source solutions will lower the barrier for creating integrated visuomotor datasets. Because of the rarity of such datasets for full-body movement and the current difficulty of producing them, these technical deliverables are a central contribution of the proposal, but one that is deeply intertwined with the scientific goals.

SA1: Information gathering and motor planning during full-body movement through real-world environments. There is a lack of normative baseline data on how individuals use their vision to actively select the information that guides walking through complex environments. Our approach will be to collect an integrated visuomotor dataset (including body movements, eye movements and the environment) in 50 adults with typical vision and motor function. We will analyze motor planning strategies, assess how the moment-to-moment instability of gait impacts gaze behavior, and identify adaptive gaze patterns. More generally, we will model the coordination of gaze/gait during visually-guided walking, establishing typical gaze patterns in the context of the motor behavior. *SA1* will provide a comprehensive description of the sensorimotor processes that underlie visually-guided walking. *Technical Deliverables (SA1):* comprehensive visuomotor dataset; open-source documentation of the hardware infrastructure for collecting low-cost, high-quality integrated visuomotor data; open-source software processing pipeline for integrating multi-modal dataset into the same spatial reference frame.

SA2: Testing the spatial and temporal dynamics of visual information gathering and motor planning. We have developed a body- and gaze-contingent augmented reality ground plane (3m x 10m) for the presentation of arbitrary 2D walking paths. Preliminary results show that the manipulation of foothold sparsity

results in modulation of gaze/gait behavior that mimics the changes due to different terrain complexity observed in natural environments. We will manipulate the availability of visual information based on current body position and gaze location to identify the role of temporal dynamics and peripheral processing in the visual information gathering that supports walking. *SA2* will identify when and where in the visual field the critical information for foothold selection during walking occurs. *Technical Deliverables (SA2):* open source hardware specifications for "augmented reality ground-plane"; open-source software processing pipeline for integrating laboratory-based multi-modal data into the same spatial reference frame

SA3: Impact of Divided on Attention on the visuomotor control of walking. The data collection effort described in SA1 will include a divided attention condition. Participants will be asked to walk while talking to an experimenter and/or completing tasks on their phone. Prior work across gait and postural control studies demonstrates that there is a cost to divided attention [CITE]. We will measure the impact of divided attention on the coordination of gaze/gait during full-body movement through real-world environments. *SA3* will provide insight into how visual information gathering and motor planning resources are allocated when individuals are simultaneously engaged in two tasks. *Technical Deliverables (SA3): divided attention extension to comprehensive visuomotor dataset (see SA1)*.

A. Significance

A.1. Instructions. Optional subtitle

Explain the importance of the problem or critical barrier to progress in the field that the proposed project addresses.

Explain how the proposed project will improve scientific knowledge, technical capability, and/or clinical practice in one or more broad fields.

Describe how the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field will be changed if the proposed aims are achieved.

A.2. Subheading.

Table 1: Example Table

City	N[a]	%Silly
San Diego	289	41%
Seattle	262	32%
Galveston	261	15%
St Louis	269	7%
New York	271	4%
Baltimore	231	2%
Total	1,586	21%

[a]All participants clowns.

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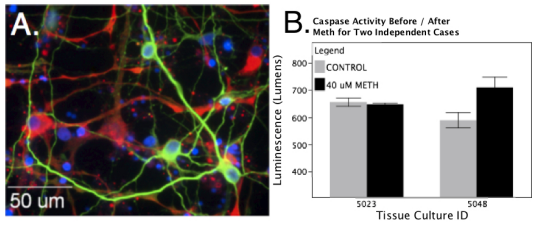

Figure 1: Example wrapped figure. (A) Impressive microscopy image. (B) Impressive data.

A.3. Another subheading: optional subtitle.

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A.4. Yet another subheading.

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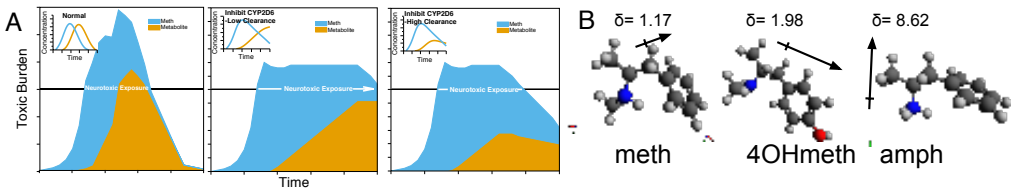

Figure 2: Big Figure legend Big Figure legend Big Figure legend Big Figure legend Big Figure legend Big Figure legend Big Figure legend Big Figure legend Big Figure legend.

B. Innovation

B.1. Instructions.

Explain how the application challenges and seeks to shift current research or clinical practice paradigms.

Describe any novel theoretical concepts, approaches or methodologies, instrumentation or interventions to be developed or used, and any advantage over existing methodologies, instrumentation, or interventions.

Explain any refinements, improvements, or new applications of theoretical concepts, approaches or methodologies, instrumentation, or interventions.

7. Inclusion of Women and Minorities

Refer to Part II, Supplemental Instructions for Preparing the Human Subjects Section of the Research Plan. This section is required for applicants answering "yes" to the question "Are human subjects involved?" on the R&R Other Project Information form and the research does not fall under Exemption 4.

6. Protection of Human Subjects

Refer to Part II, Supplemental Instructions for Preparing the Human Subjects Section of the Research Plan.

This section is required for applicants answering "yes" to the question "Are human subjects involved?" on the R&R Other Project Information form. If the answer is "No" to the question but the proposed research involves human specimens and/or data from subjects applicants must provide a justification in this section for the claim that no human subjects are involved.

Do not use the protection of human subjects section to circumvent the page limits of the Research Strategy.

9. Inclusion of Children

Refer to Supplemental Instructions for Preparing the Human Subjects Section of the Research Plan, Sections 4.4 and 5.7. For applicants answering "Yes" to the question "Are human subjects involved" on the R&R Other Project Information Form and the research does not fall under Section 4, this section is required.

10. Vertebrate Animals

If Vertebrate Animals are involved in the project, address each of the five points below. This section should be a concise, complete description of the animals and proposed procedures. While additional details may be included in the Research Strategy, the responses to the five required points below must be cohesive and include sufficient detail to allow evaluation by peer reviewers and NIH staff. If all or part of the proposed research involving vertebrate animals will take place at alternate sites (such as project/performance or collaborating site(s)), identify those sites and describe the activities at those locations. Although no specific page limitation applies to this section of the application, be succinct. Failure to address the following five points will result in the application being designated as incomplete and will be grounds for the PHS to defer the application from the peer review round. Alternatively, the application's impact/priority score may be negatively affected.

If the involvement of animals is indefinite, provide an explanation and indicate when it is anticipated that animals will be used. If an award is made, prior to the involvement of animals the grantee must submit to the NIH awarding office detailed information as required in points 1-5 above and verification of IACUC approval. If the grantee does not have an Animal Welfare Assurance then an appropriate Assurance will be required (See Part III, Section 2.2 Vertebrate Animals for more information). The five points are as follows:

1. Provide a detailed description of the proposed use of the animals in the work outlined in the Research Strategy section. Identify the species, strains, ages, sex, and numbers of animals to be used in the proposed work.

2. Justify the use of animals, the choice of species, and the numbers to be used. If animals are in short supply, costly, or to be used in large numbers, provide an additional rationale for their selection and numbers.

3. Provide information on the veterinary care of the animals involved.

4. Describe the procedures for ensuring that discomfort, distress, pain, and injury will be limited to that which is unavoidable in the conduct of scientifically sound research. Describe the use of analgesic, anesthetic, and tranquilizing drugs and/or comfortable restraining devices, where appropriate, to minimize discomfort, distress, pain, and injury.

5. Describe any method of euthanasia to be used and the reasons for its selection. State whether this method is consistent with the recommendations of the American Veterinary Medical Association (AVMA) Guidelines on Euthanasia. If not, include a scientific justification for not following the recommendations.

Do not use the vertebrate animal section to circumvent the page limits of the Research Strategy.

11. Select Agent Research

Select Agents are hazardous biological agents and toxins that have been identified by DHHS or USDA as having the potential to pose a severe threat to public health and safety, to animal and plant health, or to animal and plant products. CDC maintains a list of these agents. See http://www.cdc.gov/od/sap/docs/salist.pdf.

12. Multiple PD/PI Leadership Plan

For applications designating multiple PD/PIs, a leadership plan must be included. A rationale for choosing a multiple PD/PI approach should be described. The governance and organizational structure of the leadership team and the research project should be described, including communication plans, process for making decisions on scientific direction, and procedures for resolving conflicts. The roles and administrative, technical, and scientific responsibilities for the project or program should be delineated for the PD/PIs and other collaborators.

If budget allocation is planned, the distribution of resources to specific components of the project or the individual PD/PIs should be delineated in the Leadership Plan. In the event of an award, the requested allocations may be reflected in a footnote on the Notice of Grant Award.

13. Consortium/Contractual Arrangements

Explain the programmatic, fiscal, and administrative arrangements to be made between the applicant organization and the consortium organization(s). If consortium/contractual activities represent a significant portion of the overall project, explain why the applicant organization, rather than the ultimate performer of the activities, should be the grantee. The signature of the Authorized Organization Representative on the SF424 (R&R) cover component (Item 17) signifies that the applicant and all proposed consortium participants understand and agree to the following statement:

The appropriate programmatic and administrative personnel of each organization involved in this grant application are aware of the agency's consortium agreement policy and are prepared to establish the necessary inter-organizational agreement(s) consistent with that policy.

15. Resource Sharing

NIH considers the sharing of unique research resources developed through NIH-sponsored research an important means to enhance the value and further the advancement of the research. When resources have been developed with NIH funds and the associated research findings published or provided to NIH, it is important that they be made readily available for research purposes to qualified individuals within the scientific community. See Part III, 1.5 Sharing Research Resources.

1. Data Sharing Plan: Investigators seeking $500,000 or more in direct costs (exclusive of consortium F&A) in any year are expected to include a brief 1-paragraph description of how final research data will be shared, or explain why data-sharing is not possible. Specific Funding Opportunity Announcements may require that all applications include this information regardless of the dollar level. Applicants are encouraged to read the specific opportunity carefully and discuss their data-sharing plan with their program contact at the time they negotiate an agreement with the Institute/Center (IC) staff to accept assignment of their application. See Data-Sharing Policy or http://grants.nih.gov/grants/guide/notice- files/NOT-OD-03-032.html.

2. Sharing Model Organisms: Regardless of the amount requested, all applications where the development of model organisms is anticipated are expected to include a description of a specific plan for sharing and distributing unique model organisms or state why such sharing is restricted or not possible. See Sharing Model Organisms Policy, and NIH Guide NOT-OD-04-042.

3. Genome Wide Association Studies (GWAS): Applicants seeking funding for a genome-wide association study are expected to provide a plan for submission of GWAS data to the NIH-designated GWAS data repository, or an appropriate explanation why submission to the repository is not possible. GWAS is defined as any study of genetic variation across the entire genome that is designed to identify genetic associations with observable traits (such as blood pressure or weight) or the presence or absence of a disease or condition. For further information see Policy for Sharing of Data Obtained in NIH Supported or Conducted Genome-Wide Association Studies, NIH Guide NOT-OD-07-088, and http://grants.nih.gov/grants/gwas/.