RESSALVA

Atendendo a solicitação do(a) autor(a), Matheus Belizario Brito, o texto completo deste documento será disponibilizado somente a partir de 12/09/2028.

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DO MOVIMENTO – INTERUNIDADES

MATHEUS BELIZARIO BRITO

ENVIRONMENTAL CONSTRAINTS ON PERCEPTION AND ACTION: EFFECTS OF HYPOXIA AND COLD EXPOSURE ON AFFORDANCE PERCEPTION, POSTURAL CONTROL, AND GAZE BEHAVIOUR

Bauru - SP

2026

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DO MOVIMENTO – INTERUNIDADES

MATHEUS BELIZARIO BRITO

ENVIRONMENTAL CONSTRAINTS ON PERCEPTION AND ACTION: EFFECTS OF HYPOXIA AND COLD EXPOSURE ON AFFORDANCE PERCEPTION, POSTURAL CONTROL, AND GAZE BEHAVIOUR

Doctoral thesis presented as a requirement for obtaining the title of Doctor at São Paulo State University "Júlio de Mesquita Filho" – School of Sciences (Bauru), Department of Physical Education, Postgraduate Program in Movement Sciences, area of concentration Biodynamics of Movement, under the supervision of Dra. Paula Fávaro Polastri Zago

Bauru
2026

UNIVERSIDADE ESTADUAL PAULISTA

Câmpus de Bauru

Faculdade de Ciências

ATA DA DEFESA PÚBLICA DA TESE DE DOUTORADO DE MATHEUS BELIZARIO BRITO, DISCENTE DO PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DO MOVIMENTO, DA FACULDADE DE CIÊNCIAS - CÂMPUS DE BAURU.

Aos 11 de setembro de 2026, às 14h30min, por meio de Videoconferência, realizou-se a defesa de TESE DE DOUTORADO de MATHEUS BELIZARIO BRITO, intitulada "ENVIRONMENTAL CONSTRAINTS ON PERCEPTION AND ACTION: EFFECTS OF HYPOXIA AND COLD EXPOSURE ON AFFORDANCE PERCEPTION, POSTURAL CONTROL, AND GAZE BEHAVIOUR", sob orientação da Profa. Dra. Paula Favaro Polastri Zago. A Comissão Examinadora foi constituída pelos seguintes membros: Professor Titular SERGIO TOSI RODRIGUES (Participação Presencial) do(a) Departamento de Educação Física / UNESP / Câmpus de Bauru - FC, Prof. Dr. RENATO DE MORAES (Participação Virtual) do(a) Programa de Pós-graduação em Educação Física e Esporte /Universidade de São Paulo - Escola de Educação Física e Esportes de Ribeirão Preto - SP, Prof. Dr. CARLOS AUGUSTO KALVA FILHO (Participação Virtual) do(a) Departamento de Educação Física / UNESP, Profa. Dra. NATALIA MADALENA RINALDI (Participação Virtual) do(a) Centro de Educação Física e Desportos / Universidade Federal do Espirito Santo -ES, Dr. GUSTAVO DE ANDRADE SILVA (Participação Virtual) do(a) Centro de Formação em Políticas Públicas e Tecnologias Sociais (CFPPTS) / Universidade Federal do Sul da Bahia, Após a exposição pelo doutorando e arguição pelos membros da Comissão Examinadora que participaram do ato, de forma presencial e/ou virtual, o discente recebeu o conceito final: APROVADO. Nada mais havendo, foi lavrada a presente ata, que após lida e aprovada, foi assinada pelo(a) Presidente(a) da Comissão Examinadora.

Professor Titular SERGIO TOSI RODRIGUES

gov.br Documento assinado digitalmente
SERGIO TOSI RODRIGUES
Data: 12/09/2026 12:38:28-0300
Verifique em https://validar.iti.gov.br

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru

B862e

Brito, Matheus Belizario
Environmental constraints on perception and action: effects of hypoxia and cold exposure on affordance perception, postural control, and gaze behaviour / Matheus Belizario Brito. -- Bauru, 2026
190 p.

Tese (doutorado) - Universidade Estadual Paulista (UNESP), Faculdade de Ciências, Bauru
Orientadora: Paula Fávaro Polastri Zago

1. Comportamento motor. 2. Percepção visual. 3. Controle postural. 4. Hipóxia. 5. Exposição ao frio. I. Título.

Sistema de geração automática de fichas catalográficas da Unesp. Dados fornecidos pelo autor(a).

I dedicate this thesis to my **family**.
Everything I have achieved is the result of the
love I received, the values I learned, and the
people who never stopped believing in me.

RECOGNITION

R1. Acknowledgement

First and foremost, I thank God for hearing my prayers and for granting me strength, wisdom, guidance, and blessings throughout this entire journey.

To my parents, Sueli (in memoriam) and Paulo, I express my eternal gratitude for your teachings, unconditional love, and countless sacrifices that made it possible for me to reach this point. Thank you for believing in me, supporting me in every decision, and playing a fundamental role in shaping the person I am today. Nowadays, not everyone has the privilege of pursuing and completing postgraduate education. Thanks to your dedication, hard work, and unwavering support, I can proudly say that I am one of those privileged individuals.

To my family members, thank you for your affection, encouragement, and for always keeping me in your thoughts, even during the periods when distance and academic commitments kept me away. Your support reminds me that, regardless of the challenges and obstacles life may bring, I will always have a place to call home and people to whom I can return.

To the friends who have remained by my side throughout the years, I offer my sincere gratitude. I will not mention names here, but you know the special place you hold in my life. I am often amazed by the strength and longevity of our friendships. You are role models to me, and this achievement carries a little piece of each one of you. I sincerely hope you achieve all your goals and aspirations. No matter the distance, I will always be proud of and happy for your accomplishments.

To all members of LIVIA who have been part of my journey from my very first steps in research to the present day, thank you for the knowledge, companionship, discussions, collaborations, and daily support. Whenever I walk into the laboratory, I feel both proud and amazed by how much it has grown and evolved over the years through the dedication, commitment, and hard work of its members.

To the BTC/Proeste volleyball team, thank you for the trust you placed in my work and for being an important support network throughout this journey. I apologize for my absences and for not being able to dedicate as much attention as I would have liked during these final months. I am certain that this will change in the future. Beyond that, being part of this team has been fundamental to my growth, both professionally and personally.

To the United Kingdom, where I spent a year during my doctoral exchange, thank you for the experiences, memories, and lessons that will stay with me forever. Leaving my country alone for the first time was not simply an event—it was a great adventure. Thank you for the friendships I built, the experiences I lived, and for teaching me so much about different cultures in such a short period of time. I hope to return very soon.

To the University of Portsmouth, thank you for opening doors to me, for providing the opportunity to conduct part of this research, and for welcoming me throughout my exchange period. The experience of working in another country for an entire year was truly transformative and had a profound impact on my academic, professional, and personal development.

To Professors Tom Williams and Heather Massey, thank you for your generosity in sharing your knowledge, for your welcoming attitude, and for the valuable lessons you taught me, particularly in the areas of physiology and experimental procedures. Your guidance and advice broadened my perspective and sparked a lasting interest in this field of research that will undoubtedly remain part of my future academic endeavours.

To Professors Harry Ramsey and Matt Miller-Dicks, I am deeply grateful for your guidance, your constant willingness to engage in scientific discussions, and your invaluable contributions to the interpretation of the findings presented in this thesis. More importantly, thank you for showing me that being a professor and supervisor goes far beyond research and teaching. It also means demonstrating empathy, kindness, and support in ways that are often outside one's formal responsibilities. I will never forget how you helped me find a place to live during my first week in the UK, nor the stories and conversations we shared during our meetings. I wish you both happiness and continued success in every aspect of your lives. Professional success is something you have already achieved; now I wish you a lifetime of personal fulfilment as well.

To Professor Martina Navarro, thank you for being one of my greatest pillars during my exchange period and for remaining present throughout these years, offering support, encouragement, and essential contributions to my academic journey. Words cannot fully express how much you have helped and inspired me throughout my doctoral studies. I have witnessed firsthand your dedication to research: developing projects, leading meetings, participating in data collections, and working tirelessly to turn ideas into reality. You are a source of inspiration and an example for anyone pursuing a career in academia. I sincerely hope to remain one of your collaborators and research partners for many years to come.

To Professors Fábio and Sérgio, I express my deepest gratitude for your guidance, for the knowledge you shared, for your patience during challenging moments, and above all, for the trust you placed in me throughout this journey. Much of what I have achieved would not have been possible without the opportunities and teachings you provided. I also hope that we can continue developing projects and collaborations together in the future.

To my supervisor, Professor Paula, when I first started working with you in 2013, I knew that this partnership would change my life. Without a doubt, it did. Thanks to your guidance, I achieved things I never imagined possible. Throughout these thirteen years, I experienced many challenges, and in every one of them you knew exactly how to guide me in the best possible way.

There is one phrase you told me that I will carry with me forever: *"Matheus, I would like you to take the good things I do and carry them with you. The things you disagree with, or the mistakes I make, improve upon them so that your future students can do the same."* I am certain that I will never forget those words. They represent not only your way of mentoring, but also the humility and generosity that make you such an exceptional supervisor. I sincerely hope that, throughout these thirteen years, I have lived up to the expectations you placed in me.

I gratefully acknowledge the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the financial support that made my research experience at the University of Portsmouth possible. The opportunity to conduct this work in an international research

environment was fundamental to broadening my academic training and establishing valuable scientific collaborations.

To all the people I met at this University, thank you for helping me understand what it truly means to be part of UNESP. I carry with me not only the pride of belonging to this institution, but also the responsibility, values, and commitment that it represents.

Finally, I would like to thank everyone who, in one way or another, contributed to the completion of this work and to the journey that led me here. Every gesture of support, encouragement, friendship, and guidance played an important role in this path.

And here I am, closing yet another chapter of my academic journey. My most sincere thanks to all of you.

R.2 – Agradecimentos

Agradeço, primeiramente, a Deus, por ouvir minhas orações e por me conceder força, sabedoria, luz e bênçãos ao longo de toda esta trajetória.

Aos meus pais, Sueli (in memoriam) e Paulo, minha eterna gratidão pelos ensinamentos, pelo amor incondicional e pelos inúmeros sacrifícios realizados para que eu pudesse chegar até aqui. Obrigado por acreditarem em mim, por me apoiarem em cada decisão e por serem fundamentais na formação da pessoa que sou hoje. Nos dias atuais, nem todos têm o privilégio de ingressar e concluir uma pós-graduação. Graças ao empenho, à dedicação e ao amor de vocês, hoje posso dizer que faço parte desse grupo de privilegiados.

Aos meus familiares, agradeço pelo carinho, pela torcida e por sempre se lembrarem de mim, mesmo nos períodos em que a distância e os compromissos acadêmicos me mantiveram ausente. Isso me mostra que, independentemente das dificuldades e barreiras impostas pela vida, sempre terei um lugar para chamar de casa e pessoas para quem retornar.

Aos amigos que permanecem em minha vida, deixo meu sincero agradecimento. Não ouso citar nomes, mas vocês sabem o espaço que ocupam em minha história. Muitas vezes me surpreendo com a força e a longevidade das nossas amizades. Vocês são exemplos para mim, e saibam que esta conquista também carrega um pouco de cada um de vocês. Desejo, de coração, que alcancem todos os seus objetivos e realizações. Estarei sempre feliz e orgulhoso, mesmo à distância, por cada uma de suas conquistas.

A todos os integrantes do LIVIA, que fizeram parte da minha trajetória desde os primeiros passos na pesquisa até o presente momento, agradeço pelos ensinamentos, pela convivência, pelas discussões, pelas parcerias e pelo apoio diário. Sempre que entro no laboratório, sinto alegria e orgulho ao perceber o quanto ele cresceu e se desenvolveu ao longo dos anos graças ao trabalho árduo, comprometido e apaixonado de seus integrantes.

À equipe de voleibol BTC/Proeste, agradeço pela confiança depositada em meu trabalho e por constituírem uma importante rede de apoio ao longo desta caminhada. Peço desculpas pelas ausências e pela atenção reduzida nos últimos meses. Tenho certeza de que, a partir de agora, poderei retribuir de forma mais presente tudo o que recebi de vocês. O convívio com essa equipe foi fundamental para o meu crescimento, tanto profissional quanto pessoal.

Ao Reino Unido, país onde vivi durante um ano de intercâmbio, agradeço pelas experiências vividas, pelas lembranças construídas e pelos ensinamentos proporcionados. Sair sozinho do próprio país pela primeira vez não é apenas uma viagem; é uma verdadeira aventura, capaz de transformar a forma como enxergamos o mundo e a nós mesmos. Obrigado pelos amigos que fiz, pelas histórias que vivi e por tudo o que aprendi culturalmente em tão pouco tempo. Espero retornar em breve.

À University of Portsmouth, agradeço por abrir suas portas para mim, pela oportunidade de realizar parte desta pesquisa e pela acolhida durante todo o período do intercâmbio. A experiência de trabalhar em outro país durante um ano teve um impacto profundo na minha formação acadêmica, profissional e humana, deixando marcas que levarei para toda a vida.

Aos professores Tom Williams e Heather Massey, agradeço pelos conhecimentos compartilhados, pela receptividade e pelos ensinamentos, especialmente no campo da fisiologia

e dos procedimentos experimentais. Seus conselhos ampliaram minha visão sobre essa área de pesquisa e certamente continuarão influenciando minhas futuras linhas de investigação.

Aos professores Harry Ramsey e Matt Miller-Dicks, minha sincera gratidão pela orientação, pela disponibilidade constante para discussões científicas e pelas valiosas contribuições para a interpretação dos resultados deste trabalho. Mais do que excelentes pesquisadores, vocês me mostraram que ser professor e orientador vai muito além da produção científica. Significa demonstrar empatia, acolhimento e preocupação genuína com as pessoas. Nunca esquecerei o apoio recebido na minha chegada ao Reino Unido, quando me ajudaram a encontrar um lugar para morar, nem das histórias e conversas que tornaram nossas reuniões tão especiais. Desejo a vocês muitas felicidades e realizações. O sucesso profissional vocês já conquistaram; agora desejo que continuem colecionando momentos felizes ao lado das pessoas que amam.

À professora Martina Navarro, agradeço por ter sido um dos principais pilares durante o período do intercâmbio e por permanecer presente ao longo destes anos, oferecendo apoio, incentivo e contribuições fundamentais para esta trajetória acadêmica. Não existem palavras suficientes para expressar o quanto você me ajudou e me inspirou durante o doutorado. Vi de perto sua dedicação à ciência, conduzindo projetos, participando de coletas, organizando equipes e transformando ideias em realidade. Você é um exemplo de pesquisadora, profissional e ser humano. Espero que possamos continuar colaborando e compartilhando projetos por muitos anos.

Aos professores Fábio e Sérgio, expresso minha profunda gratidão pela orientação, pelos conhecimentos compartilhados, pela paciência nos momentos mais desafiadores e, principalmente, pela confiança depositada em mim ao longo deste percurso. Muito do que conquistei até aqui só foi possível graças aos ensinamentos e às oportunidades que recebi de vocês. Espero que possamos continuar construindo parcerias e desenvolvendo projetos juntos no futuro.

À minha orientadora, professora Paula, quando comecei a trabalhar com você, em 2013, eu já imaginava que essa parceria teria um impacto importante na minha vida. O que eu não imaginava era o quanto ela transformaria minha trajetória. Graças à sua orientação, conquistei objetivos que jamais pensei ser capaz de alcançar. Ao longo desses anos, vivi momentos de alegria, dúvidas, desafios e crescimento, e em cada um deles encontrei em você apoio, orientação e confiança.

Existe uma frase sua que levarei comigo para sempre: *"Matheus, eu gostaria que você pegasse as coisas boas que eu realizo e levasse para você. As ruins e aquelas com as quais você não concorda, melhore-as para que seus futuros orientandos também possam fazer o mesmo."* Essa frase representa não apenas a sua forma de orientar, mas também a humildade e a generosidade que fazem de você uma profissional tão admirável. Espero, sinceramente, ter correspondido às expectativas depositadas em mim ao longo desses anos.

Às pessoas que conheci nesta Universidade, agradeço por contribuírem para que eu compreendesse o verdadeiro significado de ser unespiano. Levo comigo não apenas o orgulho de pertencer a esta instituição, mas também os valores, as responsabilidades e o compromisso que ela representa.

Agradeço à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pelo apoio financeiro, que tornou possível minha experiência de pesquisa na University of Portsmouth. A oportunidade de desenvolver este trabalho em um ambiente internacional de pesquisa foi fundamental para ampliar minha formação acadêmica e estabelecer valiosas colaborações científicas.

Por fim, agradeço a todos que, de alguma forma, contribuíram para a realização deste trabalho e para a construção desta trajetória. Cada gesto de apoio, incentivo, amizade ou ensinamento teve importância nesta caminhada.

Hoje encerro mais uma etapa da minha formação acadêmica. No entanto, levo comigo muito mais do que um título: levo experiências, amizades, aprendizados e memórias que farão parte de quem sou para sempre. Meus mais sinceros agradecimentos a todos.

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru



Information, Vision and Action Laboratory.

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru

CIÊNCIAS DO MOVIMENTO
PROGRAMA DE PÓS-GRADUAÇÃO

UNIVERSITY OF PORTSMOUTH

extreme environments laboratory

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Ciências - Bauru

CIÊNCIAS DO MOVIMENTO
PROGRAMA DE PÓS-GRADUAÇÃO

POTENTIAL IMPACT OF THIS RESEARCH

P1. Potential impact

The present thesis has scientific, educational, and applied impact by investigating how extreme environments, particularly hypoxia and cold exposure, influence human performance, postural control, affordance perception, and gaze behaviour. This research contributes to a more integrated understanding of the relationship between physiological state, perception, and action in contexts in which maintaining safety and functionality is essential.

Regarding the Sustainable Development Goals (SDGs), this thesis contributes to:

• SDG 3 – Good Health and Well-being, by providing evidence on how adverse environmental conditions can affect perceptual–motor processes, balance, gaze behaviour, and performance in functional tasks. These findings may support future strategies for risk prevention, training, and safety for individuals exposed to cold, hypoxic, or physically challenging environments, such as athletes, workers, military personnel, rescue teams, and drivers.

• SDG 4 – Quality Education, as this work contributes to advanced training in Movement Sciences, motor behaviour, environmental physiology, and ergonomics. The thesis integrates different areas of knowledge and uses experimental methods that may support teaching activities, academic supervision, scientific production, and the training of new researchers interested in the relationship between organism, environment, and task.

• SDG 13 – Climate Action, as it expands knowledge about human responses to extreme environmental conditions. Although the thesis does not directly investigate climate change, its results may contribute to understanding how individuals adapt to adverse environmental situations, which is relevant in view of the increasing human exposure to extreme events and contexts.

• SDG 17 – Partnerships for the Goals, as the thesis was developed in collaboration between São Paulo State University (UNESP) and the University of Portsmouth, England. This international partnership strengthened the scientific quality of the thesis, enabled the use of specialised infrastructure, and contributed to the internationalisation of postgraduate education and the development of scientific collaboration networks.

Overall, the expected impact of this thesis lies in its contribution to advancing knowledge on human behaviour to extreme environments, with implications for health, safety, education, and scientific cooperation. The findings demonstrate that physiological changes do not necessarily lead directly to performance failure, but may modify the way individuals perceive, visually explore, and regulate their actions under environmental constraints.

P2. Impacto potencial

A presente tese apresenta impacto científico, educacional e aplicado ao investigar como ambientes extremos, especialmente hipóxia e exposição ao frio, influenciam o desempenho humano, o controle postural, a percepção de affordances e o comportamento do olhar. A pesquisa contribui para uma compreensão mais integrada da relação entre estado fisiológico, percepção e ação em contextos nos quais a manutenção da segurança e da funcionalidade é essencial.

Em relação aos objetivos de desenvolvimento sustentável (ODS) a tese contribui para:

- ODS 3 – Saúde e Bem-estar, evidenciando como condições ambientais adversas podem afetar processos perceptivo-motores, equilíbrio, comportamento visual e desempenho em tarefas funcionais. Esses achados podem auxiliar futuras estratégias de prevenção de riscos, treinamento e segurança para indivíduos expostos a ambientes frios, hipóxicos ou fisicamente desafiadores, como atletas, trabalhadores, militares, equipes de resgate e condutores.
- ODS 4 – Educação de Qualidade, o trabalho contribui para a formação avançada em Ciências do Movimento, comportamento motor, fisiologia ambiental e ergonomia. A tese integra diferentes áreas do conhecimento e utiliza métodos experimentais que podem apoiar atividades de ensino, orientação, produção científica e formação de novos pesquisadores interessados na relação entre organismo, ambiente e tarefa.
- ODS 13 – Ação contra a Mudança Global do Clima, pois amplia o conhecimento sobre respostas humanas a condições ambientais extremas. Embora a tese não investigue diretamente mudanças climáticas, seus resultados podem contribuir para compreender como indivíduos se adaptam a situações ambientais adversas, o que é relevante diante do aumento da exposição humana a eventos e contextos extremos.
- ODS 17 – Parcerias e Meios de Implementação, uma vez que foi desenvolvida em colaboração entre a Universidade Estadual Paulista (UNESP) e a University of Portsmouth. Essa parceria internacional fortaleceu a qualidade científica da tese, possibilitou o uso de infraestrutura especializada e contribuiu para a internacionalização da pós-graduação e para a construção de redes de colaboração científica.

De forma geral, o impacto esperado desta tese está na contribuição para o avanço do conhecimento sobre comportamento humano em ambientes extremos, com implicações para saúde, segurança, educação e cooperação científica. Os resultados demonstram que alterações fisiológicas nem sempre levam diretamente à falha no desempenho, mas podem modificar a forma como os indivíduos percebem, exploram visualmente e regulam suas ações sob restrições ambientais.

BRITO, M. B. **Environmental constraints on perception and action: effects of hypoxia and cold exposure on affordance perception, postural control, and gaze behaviour.** 2026. 190p. Thesis (PhD in Movement Sciences) - UNESP, Faculty of Sciences, Bauru, 2026.

T1. ABSTRACT

Human performance in extreme environments has traditionally been investigated from a physiological perspective, emphasising how stressors such as hypoxia and cold exposure challenge homeostasis and influence physical and cognitive functioning. However, less is known about how changes in physiological state influence perception–action processes and visual behaviour. This thesis investigated how acute hypoxia and cold-water immersion affect different components of perception and action, including postural control, affordance perception, maximum action capabilities, perceptual–motor calibration, motor performance, simulated driving, and gaze behaviour. A systematic review first synthesised evidence on the effects of hypoxia and cold exposure on motor, perceptual–motor, and gaze-related outcomes, highlighting variability across environmental stressor, exposure characteristics, and task demands. This was followed by three experimental studies. The first experimental study examined the effects of acute hypoxia before and after light physical exercise. Hypoxia produced clear physiological perturbation and changes in postural control, while perceived and actual maximum action capabilities remained comparatively stable. Perceptual–motor calibration showed selective changes, particularly during the leaping task. The second experimental study examined cold-water immersion and subsequent recovery under cool and heated rewarming conditions. Cold exposure produced physiological and manual perturbations, while broader simulated driving performance remained comparatively stable despite changes in specific aspects of vehicle control. The third experimental study examined eye-movement showed changes in the spatial organisation of visual exploration, observed more consistently during motorway driving than during the slalom task. These changes evolved throughout recovery, with patterns during heated rewarming consistent with an earlier return towards baseline, although recovery conditions were not directly compared. Collectively, the findings demonstrate that environmental stress does not produce uniform changes across physiological, motor, perceptual, and visual outcomes. Instead, behavioural responses depend on the component examined, task demands, and the stage of exposure or recovery. By integrating physiological, perceptual–motor, performance, and gaze-related outcomes, this thesis demonstrates that substantial physiological perturbation can occur without disrupting all components of perception and action.

Keywords: extreme environments, gaze behaviour, affordances.

BRITO, M. B. **Restrições ambientais na percepção e ação: efeitos da hipóxia e da exposição ao frio na percepção de affordances, controle postural e comportamento do olhar.** 2026. 190f. Tese (Doutorado em Ciências do Movimento) – UNESP, Faculdade de Ciências, Bauru, 2026.

T2. RESUMO

O desempenho humano em ambientes extremos tem sido tradicionalmente investigado a partir de uma perspectiva fisiológica, enfatizando como estressores como a hipóxia e a exposição ao frio desafiam a homeostase e influenciam o funcionamento físico e cognitivo. Entretanto, ainda se sabe menos sobre como mudanças no estado fisiológico influenciam os processos de percepção–ação e o comportamento visual. Esta tese investigou como a hipóxia aguda e a imersão em água fria afetam diferentes componentes da percepção e da ação, incluindo controle postural, percepção de affordances, capacidades máximas de ação, calibração perceptivo-motora, desempenho motor, direção simulada e comportamento do olhar. Inicialmente, uma revisão sistemática sintetizou evidências sobre os efeitos da hipóxia e da exposição ao frio em desfechos motores, perceptivo-motores e relacionados ao comportamento do olhar, destacando variações de acordo com o estressor ambiental, as características da exposição e as demandas da tarefa. O primeiro estudo experimental examinou a hipóxia aguda antes e após exercício físico leve. A hipóxia produziu clara perturbação fisiológica e alterações no controle postural, enquanto as capacidades máximas de ação percebidas e reais permaneceram comparativamente estáveis. A calibração perceptivo-motora apresentou alterações seletivas, particularmente na tarefa de salto. O segundo estudo experimental examinou a imersão em água fria e a recuperação subsequente em condições de reaquecimento em ambiente frio e aquecido. A exposição ao frio produziu alterações fisiológicas e na função manual, enquanto o desempenho geral na direção simulada permaneceu comparativamente estável, apesar de mudanças em aspectos específicos do controle do veículo. O terceiro estudo analisou os movimentos oculares demonstrando alterações na organização espacial da exploração visual, observadas de forma mais consistente durante a direção em rodovia do que durante o slalom. Essas alterações evoluíram ao longo da recuperação, com os padrões durante o reaquecimento em ambiente aquecido consistentes com um retorno mais precoce em direção aos valores basais, embora as condições de recuperação não tenham sido comparadas diretamente. Em conjunto, os resultados demonstram que o estresse ambiental não produz alterações uniformes nos desfechos fisiológicos, motores, perceptivos e visuais. As respostas comportamentais dependem do componente analisado, das demandas da tarefa e do estágio de exposição ou recuperação. Ao integrar desfechos fisiológicos, perceptivo-motores, de desempenho e relacionados ao comportamento do olhar, esta tese demonstra que perturbações fisiológicas substanciais podem ocorrer sem alterações correspondentes em todos os componentes da percepção e da ação.

Palavras chaves: Ambientes extremos, comportamento do olhar, affordances.

LIST OF FIGURES

Figure 2.1. Physiological and functional effects of hypoxia and cold exposure. The figure summarizes the main physiological pathways through which hypoxia and cold exposure influence human functioning. Generated by the author using ChatGPT (DALL-E 3 model), OpenAI, on July 11, 2026……..……..……..18

Figure 2.2. Conceptual framework illustrating the relationship between environmental information, perception–action, organismic state, and perceptual–motor calibration under acute environmental stress. Generated by the author using ChatGPT (DALL-E 3 model), OpenAI, on July 11, 2026……..……29

Figure 2.3. Overview of current evidence and main gaps in the literature regarding the effects of hypoxia and cold exposure on perceptual–motor behaviour Generated by the author using ChatGPT (DALL-E 3 model), OpenAI, on July 11, 2026…….……34

Figure 3.1. Summary of the search strategy and selection process based on included and excluded studies. The figure presents the identification, screening, eligibility, and inclusion stages used to select studies for the literature review…….45

Figure 4.1. Schematic overview of the experimental protocols for Experiments 1 and 2. Experiment 1 included a sequence of rest, balance assessment, perceived and actual maximum action capabilities, and treadmill walking under normoxic (FiO_2: 0.21) and hypoxic (FiO_2: 0.13) conditions. Experiment 2 consisted of repeated simulated driving tasks interspersed with cold-water immersion, followed by cool (15°C) or heated (30°C) recovery conditions……..68

Figure 4.2. Participants completed a series of tasks under normoxia and hypoxia conditions (FiO_2 = 0.21 and 0.13, respectively). The protocol included (A) instrumentation and physiological monitoring, (B) bipedal and (C) single-leg stance postural assessment, (D) perceived maximum action capabilities and (E) actual maximum action capabilities, and (F) treadmill walking exercise…….70

Figure 4.3. Postural control responses across experimental conditions in the anteroposterior (AP) and mediolateral (ML) directions during bipedal and single-leg stance. The upper panels represent the mean amplitude of centre of pressure (CoP), the middle panels represent the mean velocity of CoP, and the lower panel represents the total CoP displacement. Data are presented as boxplots (median, interquartile range, and range). Conditions are represented as follows: NB (normoxia before exercise), NA (normoxia after exercise), HB (hypoxia before exercise), and HA (hypoxia after exercise). Symbols (e.g., β, #, +) denote specific pairwise comparisons as described in the text……...79

Figure 4.4. Affordance perception and action performance across experimental conditions. The upper panels display the PMAC (blue) and AMAC (red) distances for the Step (left) and Leap (right) tasks under four conditions: normoxia before exercise (NB), normoxia after activity (NA), hypoxia before exercise (HB), and hypoxia after activity (HA). Boxplots represent median, interquartile range, and total variability. The lower panel presents the perceptual-motor ratio (PMAC/AMAC), where values close to 1 indicate accurate calibration between PMAC and AMAC capabilities. Symbols (e.g., β and #) denote specific pairwise comparisons as described in the text……..….81

Figure 4.5. Overview of the experimental protocol before and after cold-water immersion. The protocol included (A) immersion in cold-water for up to 60 minutes, (B) simulated driving tasks performed immediately after immersion and at 30 and 60 minutes post-immersion, and (C) recovery procedures under controlled environmental conditions ……86

Figure 4.6. Experimental driving tasks. (A) Slalom task: participants navigated a predefined course with 17 obstacles, aiming to complete it as quickly as possible while minimizing collisions, assessing action capabilities. (B) Simulated highway driving: participants drove in a moderate-traffic environment, following traffic rules under naturalistic conditions……..88

Figure 4.7. Physiological and neuromuscular responses under cold and warm conditions. Internal temperature (°C), handgrip strength (right and left; kg), and manual dexterity (nut-and-bolt task; time in seconds) measured at rest (REST), during driving (DRIVE), and after 30 and 60 minutes (DRIVE30 and DRIVE60). Bar graphs represent mean ± standard deviation for cool and heated recovery conditions, while adjacent heatmaps illustrate the distribution of values across time points and conditions. Asterisks (*) indicate significant differences compared to REST, and hashtags (#) indicate significant differences between conditions……95

Figure 4.8. Driving performance and control variability under cold and warm conditions. Top panels: total time (s) and mean number of errors across time points (REST, DRIVE, DRIVE30, and DRIVE60). Bottom panels: variability (SD) of brake, throttle position, and steering wheel angle. Bars represent mean ± standard deviation for cool and heated recovery conditions. Asterisks (*) indicate significant differences compared to REST, and hashtags (#) indicate significant differences between conditions……..……97

Figure 4.9. Driving control variability under cold and warm conditions. (A) Brake variability, (B) throttle position variability, and (C) steering wheel angle variability, expressed as standard deviation (SD), across different time points: REST, DRIVE, DRIVE30, and DRIVE60. Bars represent mean ± standard deviation. Asterisks (*) indicate significant differences compared to REST within the same condition……99

Figure 5.1. Experimental protocol and cold-water immersion procedures. Panel A illustrates the experimental timeline. During Visit 1, participants completed a baseline driving assessment (REST). During Visits 2 and 3, participants performed up to 60 min of swimming in 15°C water

or until core temperature reached 35°C, followed by either cool rewarming (CR) or heated rewarming (HR) in a randomized and counterbalanced order. Driving assessments were performed immediately after immersion (POST), and after 30 min (POST30) and 60 min (POST60) of recovery. Panel B shows the cold-water swimming protocol performed in a temperature-controlled flume maintained at 15°C. Panel C shows the seated recovery period conducted following immersion, during which participants wore dry clothing while recovering in either a cool (15°C) or heated (30°C) environment. ……..…….117

Figure 5.2. Experimental driving tasks and simulator setup. Panel A shows the fixed-base driving simulator used during all assessments, consisting of a GT Omega ART RS9 cockpit, Logitech G29 steering wheel and pedal system, a 55-inch display, and the Neon wearable eye-tracking system. Panel B shows the slalom driving task performed on the ADAC Slalom track, which required continuous steering adjustments and precise vehicle control while navigating a cone-defined course. Panel C shows the motorway driving task performed on the Woolley Edge environment, representing a multi-lane motorway……..120

Figure 5.3. Spatial exploration variables during the slalom driving task across assessment time points following cold-water immersion under cool rewarming (CR) and heated rewarming (HR) conditions. Panels show (A) gaze area (BCEA), (B) scanpath length, (C) horizontal dispersion, and (D) vertical dispersion. Data are presented as mean ± SEM. Assessments were performed at baseline (REST), immediately after immersion (POST), after 30 min of recovery (POST30), and after 60 min of recovery (POST60). Blue circles represent the cool rewarming condition, and red squares represent the heated rewarming condition. Different Greek letters indicate significant differences between assessments within the same recovery condition (Bonferroni-adjusted post hoc comparisons, $p < .05$). Assessments sharing at least one letter are not significantly different……..124

Figure 5.4. Representative gaze heat maps during the motorway driving task under the cool rewarming condition. Panels show gaze distribution at baseline (A; REST), immediately after cold-water immersion (B; POST), after 30 min of recovery (C; POST30), and after 60 min of recovery (D; POST60). Heat maps were generated using a common colour scale across all assessments, representing the relative dwell time of gaze points (0–100%). Warmer colours indicate greater visual attention concentration. A reduction in gaze dispersion is evident at POST and POST30, followed by a partial recovery at POST60…….……..126

Figure 5.5. Spatial exploration variables during the motorway driving task across assessment time points following cold-water immersion under cool rewarming (CR) and heated rewarming (HR) conditions. Panels show (A) gaze area (BCEA), (B) scanpath length, (C) horizontal dispersion, and (D) vertical dispersion. Data are presented as mean ± SEM. Assessments were performed at baseline (REST), immediately after immersion (POST), after 30 min of recovery (POST30), and after 60 min of recovery (POST60). Blue circles represent the cool rewarming condition and red squares represent the heated rewarming condition. Symbols indicate significant differences between assessments within the same recovery condition: * =

significantly different from REST; # = significantly different from POST; β = significantly different from POST30; + = significantly different from POST60 ($p < .05$)……..……127

LIST OF TABLES

Table 3.1. Methodological quality outcomes attributed to the included studies. The table presents the quality assessment of the studies included in the literature review, indicating the methodological criteria used to evaluate each study and the corresponding scores or classifications……47

Table 3.2. Specific tasks, outcome variables, and main findings of the included studies. The table summarizes the experimental tasks, perceptual–motor, physiological, motor, and/or gaze-related variables assessed, and the principal findings reported in each study included in the literature review……49

Table 4.1. Demographic characteristics of the participants in each experiment. The table presents participant characteristics for Experiment 1 and Experiment 2, including sample size and demographic information……66

Table 4.2. Physiological and respiratory responses across experimental conditions: normoxia before exercise (NB), normoxia after exercise (NA), hypoxia before exercise (HB), and hypoxia after exercise (HA). Values are presented as mean ± standard deviation. HAR = heart rate; SpO_2 = peripheral oxygen saturation; VE = minute ventilation; VCO_2 = carbon dioxide production; VO_2 = oxygen uptake relative to body mass; $PETO_2$ = end-tidal oxygen pressure; $PETCO_2$ = end-tidal carbon dioxide pressure; FR = respiratory frequency. Different superscript letters indicate significant pairwise differences between conditions ($p < .05$). Variables analysed using Friedman tests do not include ANOVA p-values……...……76

Table 4.3. Physiological and perceptual responses across recovery conditions. Values are presented as mean ± standard deviation. REST = baseline; DRIVE = immediate post-intervention; DRIVE30 = 30 minutes after immersion; and DRIVE60 = 60 minutes after immersion. Different superscript letters indicate significant pairwise differences between time points within the same condition ($p < .05$). Variables analysed using Friedman tests do not present ANOVA p-values……..……93

Table 5.1. Visual sampling variables during the slalom and motorway driving tasks across assessment time points following cold-water immersion under cool rewarming (CR) and heated rewarming (HR) conditions. Values are presented as mean ± SD. Assessments were performed at baseline (REST), immediately after immersion (POST), after 30 min of recovery (POST30), and after 60 min of recovery (POST60). Friedman test statistics (χ^2), p-values, and Kendall's coefficient of concordance (W) are reported for each task and recovery condition. FIR = fixation rate; FD = fixation duration.....123

LIST OF ABBREVIATIONS

AMAC — Actual Maximum Action Capability
ANOVA — Analysis of Variance
AOI — Area of Interest
AP — Anteroposterior
BCEA — Bivariate Contour Ellipse Area
BP — Blood Pressure
CAPES — Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CoP — Centre of Pressure
CR — Cool Rewarming
FD — Fixation Duration
FIR — Fixation Rate
FIO_2 — Fraction of Inspired Oxygen
FR — Respiratory Frequency
HA — Hypoxia After Exercise
HB — Hypoxia Before Exercise
HAR — Heart Rate
HR — Heated Rewarming
MAC — Maximum Action Capability
ML — Mediolateral
NA — Normoxia After Exercise
NB — Normoxia Before Exercise
O_2 — Oxygen
$PETO_2$ — End-Tidal Oxygen Pressure
$PETCO_2$ — End-Tidal Carbon Dioxide Pressure
PMAC — Perceived Maximum Action Capability
POST — Immediately After Exposure
POST30 — 30 Minutes After Exposure
POST60 — 60 Minutes After Exposure
PRISMA — Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RM-ANOVA — Repeated-Measures Analysis of Variance
SD — Standard Deviation
SEM — Standard Error of the Mean
SpO_2 — Peripheral Oxygen Saturation
VE — Minute Ventilation
VCO_2 — Carbon Dioxide Production
VO_2 — Oxygen Uptake
WBGT — Wet-Bulb Globe Temperature

SUMMARY

RECOGNITION 6
R1. Acknowledgement 7
R.2 – Agradecimentos 10
POTENTIAL IMPACT OF THIS RESEARCH 16
P1. Potential impact 17
P2. Impacto potencial 18
T1. ABSTRACT 19
T2. RESUMO 20
LIST OF FIGURES 21
LIST OF TABLES 25
LIST OF ABBREVIATIONS 26
Thesis Structure and Organization 1
Chapter 1 – General Introduction 2
Chapter 2 – Theoretical Background 2
2.1 Extreme Environments and Organism–Environment Relations 2
2.2 Information for Action: Visual Behaviour, Affordances, and Perceptual–Motor Calibration 2
2.3 Perception–Action Regulation in Extreme Environments 3
Chapter 3 – Effects of hypoxia and cold-water immersion on motor performance and gaze behaviour: a systematic review 3
Chapter 4 – Task-dependent effects of extreme environments on affordance perception and action regulation: evidence from acute hypoxia and cold-water immersion 3
Chapter 5 – Cold-Water Immersion Constrains Visual Exploration During Simulated Driving: An Ecological Analysis of Eye-Movement Behaviour 4
Chapter 6 – General Discussion 4
Chapter 7 – Conclusions and Future Directions 4
CHAPTER 1. General introduction and objectives 6
Objectives 10
General objective 10
Specific objectives 10
CHAPTER 2. Theoretical background 11
2.1 Extreme Environments and Organism–Environment Relations 13

2.2 Information for Action: Visual Behaviour, Affordances, and Perceptual–Motor Calibration 20
2.3 Perception–Action Regulation in Extreme Environments 30
CHAPTER 3. Effects of hypoxia and cold exposure on motor performance and gaze behaviour: a systematic review 36
ABSTRACT 37
INTRODUCTION 38
METHODS 40
Search strategy 40
Selection criteria 41
Inclusion and exclusion criteria 42
Study selection 42
Methodological quality and risk-of-bias assessment 43
Data extraction 43
Data synthesis 43
RESULTS AND DISCUSSION 45
Study selection and sample characteristics 45
Methodological quality assessment 48
Physiological outcomes 52
Motor performance outcomes 53
Gaze behaviour and oculomotor outcomes 54
Integrated interpretation 55
Study limitations 56
CONCLUSION 56
Funding 57
CHAPTER 4. Task-dependent effects of extreme environments on affordance perception and action regulation: evidence from acute hypoxia and cold-water immersion 62
ABSTRACT 63
INTRODUCTION 64
General Methods 66
EXPERIMENT 1 69
Participants 69
Experimental Design 69

Procedures 69
Tasks and Variables 70
Statistical Analysis 73
Results 73
Physiological Responses 73
Postural Control (CoP) 77
Perception and action 80
Discussion 82
EXPERIMENT 2 85
Participants 85
Experimental Design 85
Procedures 86
Driving Tasks 87
Data analysis and Variables 88
Statistical Analysis 90
Results 91
Discussion 100
General Discussion 103
Conclusion 106
Funding 106
CHAPTER 5. Cold-Water Immersion Constrains Visual Exploration During Simulated Driving: An Ecological Analysis of Eye-Movement Behaviour 111
INTRODUCTION 113
METHODS 114
Participants 114
Experimental Design 115
Procedures 115
Driving Tasks and Eye-Tracking 117
Eye Movement and Driving Performance Analysis 120
Statistical Analysis 122
RESULTS 122
Slalom Task 122
Motorway Task 125

DISCUSSION 127
CONCLUSION 131
REFERENCES 132
CHAPTER 6. General Discussion 135
CHAPTER 7. Conclusions and Future Directions 144
Main conclusions 145
Theoretical Contributions and Practical Implications 146
General Limitations and Future Directions 147
REFERENCES 149

Thesis Structure and Organization

To achieve the proposed objectives, this thesis is organized into theoretical and experimental chapters that follow a logical and progressive sequence, as detailed below.

Chapter 1 – General Introduction

This chapter presents the general context, rationale, aims, and objectives of the thesis. It introduces extreme environments, with particular emphasis on hypoxia and cold exposure, as conditions capable of challenging physiological regulation, motor performance, and perceptual–motor behaviour. The chapter also outlines the main research gaps addressed in the thesis, including the limited integration of physiological, motor, and gaze behaviour measures in studies examining human performance under environmental stress.

Chapter 2 – Theoretical Background

This chapter establishes the theoretical foundation of the thesis by discussing how extreme environments affect the interaction between physiological regulation, motor performance, and perceptual–motor behaviour. Rather than treating hypoxia and cold exposure only as physiological stressors, this chapter considers how these conditions may alter the performer's functional state, movement regulation, and gaze behaviour during task performance.

2.1 Extreme Environments and Organism–Environment Relations

This section discusses extreme environments as conditions that impose substantial physiological and behavioural demands on the human organism. Particular emphasis is placed on hypoxia and cold exposure, considering how reduced oxygen availability and low temperatures challenge homeostasis, thermoregulation, cardiovascular responses, neuromuscular function, and perceptual–motor performance. This section establishes the physiological and functional constraints that may influence how individuals perform under environmental stress.

2.2 Information for Action: Visual Behaviour, Affordances, and Perceptual–Motor Calibration

This section presents the main concepts used to understand perception and action coupling. It discusses information detection, action capabilities, affordance perception,

(re)calibration, and perceptual–motor regulation, while also introducing gaze behaviour as an important indicator of how individuals visually explore the environment. Fixations, visual exploration, gaze dispersion, and scanpath measures are discussed as variables that may help explain how individuals detect and use information to regulate action during task performance.

2.3 Perception–Action Regulation in Extreme Environments

This section integrates evidence on how hypoxia and cold exposure may influence motor performance, gaze behaviour, and perception–action regulation. It discusses the task-dependent nature of environmental stress effects and highlights that performance changes cannot be interpreted only as physiological deterioration. Instead, changes in motor and gaze behaviour may reflect alterations in how individuals regulate action under modified bodily and environmental conditions. This section also identifies the main gaps in the literature, including the limited integration of physiological, motor, and eye-movement measures.

Chapter 3 – Effects of hypoxia and cold-water immersion on motor performance and gaze behaviour: a systematic review

This chapter presents a systematic review manuscript that synthesizes current evidence regarding the effects of hypoxia and cold-water immersion on human motor performance and gaze behaviour. The review focuses on what the literature has reported in terms of physiological responses, motor outcomes, and eye-movement measures across different tasks and exposure protocols. Rather than focusing on a purely theoretical model, this chapter brings the available empirical evidence to provide an integrated view of the topic. It identifies consistent findings, methodological limitations, and gaps in knowledge, thereby supporting the rationale for the experimental studies presented in the following chapters.

Chapter 4 – Task-dependent effects of extreme environments on affordance perception and action regulation: evidence from acute hypoxia and cold-water immersion

This chapter presents the first empirical study, which investigates how acute hypoxia and cold-water immersion, along with light exercise, influence postural control, affordance perception, and action capabilities. The study examines whether changes in physiological state are accompanied by alterations in movement regulation and perceptual–motor calibration. This chapter contributes to the thesis by examining whether hypoxia and exercise affect perception–

action regulation during tasks that require postural stability and judgements of action possibilities.

Chapter 5 – Cold-Water Immersion Constrains Visual Exploration During Simulated Driving: An Ecological Analysis of Eye-Movement Behaviour

This chapter presents the second empirical study, which investigates the effects of cold-water immersion and rewarming on gaze behaviour during simulated driving. Eye-tracking technology is used to examine how cold exposure affects visual sampling during naturalistic driving tasks. The chapter focuses on eye-movement variables such as fixation behaviour, gaze dispersion and scanpath length. It also examines whether task demands and rewarming conditions influence the recovery of motor and visual behaviour after cold-water immersion.

Chapter 6 – General Discussion

This chapter integrates the findings from the theoretical background, systematic review, and experimental studies. The discussion examines how hypoxia and cold exposure affect physiological regulation, motor performance, affordance-related judgements, postural control, driving behaviour, and gaze behaviour across different task contexts. Rather than interpreting environmental stress only as a cause of performance deterioration, this chapter discusses how individuals may maintain or modify behaviour under altered physiological conditions. The findings are interpreted from a perceptual–motor perspective, with an emphasis on task specificity, action capabilities, information use, calibration, and visual exploration.

Chapter 7 – Conclusions and Future Directions

This final chapter summarizes the main contributions of the thesis to Sport and Movement Sciences, environmental physiology, and perceptual–motor control. It highlights the importance of integrating physiological, behavioural, and eye-movement measures to better understand human performance in extreme environments. The chapter also discusses the limitations of the thesis and proposes future directions, including the need for larger and more diverse samples, longitudinal exposure protocols, ecologically valid tasks, and studies that directly combine physiological measurements with gaze behaviour and motor performance outcomes.

This organizational structure reflects the central aim of the thesis: to examine how hypoxia and cold exposure affect human motor performance and gaze behaviour, while using a perceptual–motor framework to interpret how individuals regulate action under altered environmental and physiological conditions.

CHAPTER 1. General introduction and objectives

From the earliest ocean crossings to more contemporary achievements, such as the ascent of Mount Everest, expeditions to the Arctic and Antarctic polar regions, and humanity's arrival on the Moon during Apollo 11, history has been marked by the ability of individuals to operate beyond the limits ordinarily imposed by extreme environments (Halsey; Stroud, 2012; Ward, 2003). These accomplishments represent more than technological advances or cultural milestones; they reflect the ongoing need for humans to adapt to conditions that can challenge both survival and performance (Cotter; Tipton, 2014; Tipton, 2016).

Large areas of the planet are characterised by environmental conditions that challenge human physiological and behavioural functioning, including regions exposed to extreme temperatures, reduced oxygen availability, and other environmental stressors (Burtscher et al., 2018; Cotter; Tipton, 2014; Tipton, 2016). Environments involving extreme cold, hypoxia, or other adverse conditions not only elicit substantial physiological responses but may also be associated with changes in how individuals perceive, interact with, and act within their surroundings (Castellani; Young, 2012; Mcmorris et al., 2017; Tipton et al., 2013). Under such circumstances, apparently simple activities, such as navigating through space, making rapid decisions, or interacting with objects, may become complex tasks that depend on the effective coordination between perception and action (Mcmorris et al., 2017; Virués-Ortega et al., 2004).

Traditionally, scientific literature has examined the influence of these environments predominantly from a physiological perspective (Castellani; Young, 2012; Mazzeo, 2008; Mcmorris et al., 2017; Tipton et al., 2013). Studies on hypoxia have demonstrated that reduced oxygen availability and cerebral oxygenation may impair cognitive and physical performance (Mazzeo, 2008; Mcmorris et al., 2017). Similarly, cold exposure has been associated with alterations in neuromuscular function, motor coordination, and metabolic efficiency (Castellani; Young, 2012; Tipton, 2003). Although these findings are fundamental, they capture only part of the phenomenon. More importantly, human performance in extreme environments cannot be fully explained by isolated physiological responses. Exposure to these conditions may also influence perceptual–motor regulation, including postural control, affordance perception, and gaze behaviour, in relation to changing environmental and organismic demand(Daanen, 2009; Degache et al., 2012; Orysiak; Młynarczyk; Irzmańska, 2024). Consequently, performance emerges from the continuous relationship between the individual, the task, and the surrounding environment (Warren, 1984; Yu; Stoffregen, 2012).

In this context, perception–action coupling provides an important conceptual framework for understanding how individuals regulate their actions in dynamic situations

(Fajen; Riley; Turvey, 2009; Gibson, 1979a). Perception does not operate solely as a stage preceding action. Rather, perceiving and acting form continuous and interdependent processes (Stoffregen et al., 1999a; Warren, 2006). Through movement, individuals generate and detect information that supports subsequent adjustments in behaviour (Fajen, 2005a; Michaels; Carello, 1981). This relationship may become particularly important in extreme environments because physiological and functional capabilities can change during exposure, requiring actions to be continuously calibrated to the individual's current state(Pijpers; Oudejans; Bakker, 2007; Van Andel; Cole; Pepping, 2017).

The ecological approach to perception provides a theoretical foundation for examining the relationship between perception and action (Gibson, 1979b; Michaels; Carello, 1981). By proposing that perception is grounded in the detection of information available in the environment, this perspective emphasises the functional relationship between the organism and its surroundings (Gibson, 1979b; West; Gibson, 1969). A central concept within this approach is that of affordances, which refer to opportunities for action that emerge from the relationship between environmental properties and an individual's action capabilities (Gibson, 1979a; Stoffregen, 2000; Warren, 1984). Perceiving the environment therefore involves detecting which actions are possible given the organismic and environmental conditions (Mark, 1987; Warren, 1984; Warren; Whang, 1987).

Particularly, in extreme environments, physiological alterations may modify the individual's functional capabilities and, consequently, the actions that can be successfully performed (Degache et al., 2012; Wakabayashi; Oksa; Tipton, 2015). The perception of affordances must therefore remain appropriately related to the individual's current action capabilities (Mark, 1987; Warren, 1984). This correspondence is not necessarily fixed, as it may need to be adjusted when body, task, or environmental conditions change (Fajen, 2005a; Franchak; Adolph, 2014).

This adjustment is supported by the processes of perceptual–motor calibration and recalibration. Calibration refers to the scaling of perceptual information to an individual's current action capabilities (Bingham; Pagano, 1998; Mark, 1987), whereas recalibration describes the modification of this relationship following changes in the organism–environment system (Fajen, 2007; Withagen; Michaels, 2005). In extreme environments, physiological and functional changes may occur rapidly, potentially challenging the maintenance of an accurate correspondence between perceived and actual action capabilities (Daanen, 2009; Degache et al., 2012). When recalibration does not account for these changes, perceptual judgements may

become disconnected from the actions that can be successfully performed, leading to errors in action regulation (Fajen, 2005b; Franchak; Adolph, 2014).

Gaze behaviour plays an important role in the regulation of action by supporting the detection of visual task-relevant information and the prospective control of movement (Land, 2006; Land; McLeod, 2000). During dynamic tasks, individuals direct their gaze towards locations and events that provide information about upcoming action demands, allowing movements to be continuously guided and adjusted online (Land; Lee, 1994; Lappi, 2016). Experimental evidence indicates that stressful and demanding conditions can modify gaze behaviour, including fixation frequency and duration as well as the extent and spatial distribution of visual exploration (Dehais et al., 2017; Di Stasi et al., 2013) These changes suggest that visual information sampling is continuously adapted according to both the individual's functional state and the informational demands of the task (Konstantopoulos; Chapman; Crundall, 2010; Lappi, 2016).

Understanding perceptual–motor behaviour in extreme environments therefore requires consideration of both physiological responses and behavioural regulation (Seifert et al., 2017; Vilar et al., 2012). Changes in functional capabilities may not immediately result in a deterioration in task outcomes because individuals can change how they perceive, control, and organise their actions in response to changing constraints (Davids et al., 2003; Gates; Dingwell, 2008; Seifert; Button; Davids, 2013). This adaptive capacity is consistent with the concept of degeneracy, which refers to the ability of structurally different perceptual–motor solutions to achieve the same functional outcome (Edelman; Gally, 2001; Seifert et al., 2016).

Accordingly, modifications in movement organisation or visual exploration should not necessarily be interpreted as indicators of impaired performance but may instead reflect functional reorganisation that enables the maintenance of successful behaviour under altered environmental and organismic constraints (Vilar et al., 2012; Whitacre, 2010). Consequently, measures of postural control, affordance perception, driving behaviour, and gaze control provide complementary evidence of how individuals recalibrate perception and action while reorganising behaviour to maintain functional performance under environmental stress (Franchak; Adolph, 2014; Land; Lee, 1994; Mark, 1987).

Based on this framework, the present thesis proposes that acute hypoxia and cold exposure may influence different components of perceptual and motor regulation. These effects are not expected to occur uniformly across all behaviours. Rather, their magnitude and expression may depend on the physiological demands imposed by each environmental

condition and on the perceptual and motor requirements of the task being performed. Alterations may therefore be observed in the regulation of posture and movement, in the relationship between perceived and actual action capabilities, and in gaze behaviour used to obtain visual task-relevant information, even when overall task success is preserved.

Objectives

General objective

Therefore, the general objective of this thesis was to investigate how environmental constraints, specifically acute hypoxia and cold exposure, influence perception–action coupling across tasks with varying perceptual–motor demands. The thesis examined whether changes in physiological state are accompanied by alterations in postural control, affordance perception, maximum action capabilities, perceptual–motor calibration, simulated driving performance, and gaze behaviour.

Specific objectives

The specific objectives of this thesis were:

1. To review and synthesize the available evidence on the effects of hypoxia and cold-water immersion on motor performance, perceptual–motor regulation, and gaze behaviour.
2. To examine the effects of acute hypoxia, before and after light physical exercise, on physiological responses and postural control during bipedal and single-leg stance.
3. To investigate whether acute hypoxia and light physical exercise alter perceived maximum action capabilities, actual maximum action capabilities, and perceptual–motor calibration during stepping and leaping tasks.
4. To examine the effects of cold-water immersion on physiological and perceptual responses, manual function, and simulated driving performance.
5. To investigate whether cold-water immersion modifies gaze behaviour during simulated driving tasks with different perceptual and motor demands.
6. To examine the recovery of physiological, motor, driving, and gaze-related variables following cold-water immersion under cool and heated rewarming conditions.

CHAPTER 7. Conclusions and Future Directions

Main conclusions

The findings of this thesis demonstrate that acute hypoxia and cold exposure influence perception and action selectively. Although both environmental stressors produced clear physiological perturbations, their behavioural effects depended on the component examined, the demands of the task, and the stage of exposure or recovery.

First, environmental stress altered the functional state of the organism without necessarily producing corresponding changes across all behavioural outcomes. Hypoxia affected physiological regulation and postural control, while cold-water immersion affected thermal state, manual function, vehicle-control variables, and visual exploration. These findings demonstrate that physiological perturbation alone does not determine the magnitude or expression of behavioural change.

Second, the effects of environmental stress were task dependent. Stepping and leaping remained comparatively stable under acute hypoxia and light exercise, whereas postural control showed greater sensitivity to these perturbations. Similarly, changes in gaze behaviour following cold-water immersion were observed more consistently during motorway driving than during the slalom task. Thus, the behavioural consequences of environmental stress depend on the perceptual and motor demands of the task being performed.

Third, perceived and actual maximum action capabilities during stepping and leaping were largely preserved under acute hypoxia, despite substantial physiological perturbation. However, changes in postural control and leap calibration indicate that some components of perception–action regulation may be affected even when perceived and actual action capabilities remain stable.

Fourth, cold-water immersion altered manual function and specific aspects of vehicle control while broader simulated driving performance remained comparatively stable. Eye-movement measures further showed a restriction in spatial visual exploration following cold exposure, particularly during motorway driving. These findings indicate that changes in the processes supporting task performance can occur without corresponding disruption to overall task success.

Finally, the effects of environmental stress evolved throughout exposure and recovery. Following cold-water immersion, physiological, motor, and gaze-related variables showed different temporal patterns, while visual exploration progressively moved towards baseline during recovery. Patterns during heated rewarming were consistent with an earlier return

towards baseline for some gaze measures, although recovery conditions were not directly compared.

Overall, this thesis demonstrates that the effects of acute environmental stress cannot be characterised solely in terms of performance impairment. Hypoxia and cold-water immersion produced selective changes across physiological, motor, perceptual–motor, and gaze-related outcomes, while broader measures of task performance were often preserved. Understanding human behaviour in extreme environments therefore requires consideration not only of whether a task can be successfully completed, but also of how perception and action are organised under altered environmental and physiological conditions.

Theoretical Contributions and Practical Implications

The main theoretical contribution of this thesis is to demonstrate that the behavioural consequences of environmental stress cannot be inferred solely from the magnitude of physiological perturbation or from whether task performance is preserved. Instead, the findings support a multilevel account in which physiological state, perceptual–motor organisation, and functional task outcomes may show differential sensitivity to the same environmental constraint. This distinction extends the study of human behaviour in extreme environments beyond a preserved-versus-impaired performance framework by showing that successful action may coexist with changes in the processes through which that action is organised.

A second theoretical contribution concerns the functional interpretation of preserved performance. The findings indicate that maintaining a behavioural outcome does not necessarily require preservation of the same perceptual–motor organisation. Changes in organismic conditions may be accompanied by adjustments in movement regulation, calibration, control, or information sampling while the behavioural goal remains achievable. In this sense, preserved performance may reflect the flexibility of the perception–action system to maintain functional relations with the environment under changing constraints. This interpretation is consistent with the concept of degeneracy, whereby different perceptual–motor solutions can contribute to similar functional outcomes, and reinforces the importance of examining how behaviour is organised rather than considering task success alone.

The practical implication of this distinction is that successful task performance should not automatically be interpreted as evidence that an individual is unaffected by environmental stress or has fully recovered from it. Physiological or perceptual–motor changes may not be

immediately apparent to the individual, coach, instructor, supervisor, or other professional when the expected behavioural outcome is still being achieved. Consequently, decisions about readiness to continue or resume demanding activities under or following environmental exposure should not rely exclusively on successful task completion. Where appropriate, assessment should consider indicators of physiological state together with aspects of behavioural regulation that are relevant to the demands of the activity.

This consideration becomes particularly important when apparently preserved performance is followed by a sudden change in task demands. An individual who is successfully performing under stable or predictable conditions may still be operating with altered perceptual–motor organisation, which could become functionally relevant when rapid adaptation is required. In practical settings such as sport, transportation, occupational activity, military operations, emergency response, or recreation, this means that maintaining routine performance should not necessarily be taken as evidence of unchanged capacity to respond to unexpected information or rapidly changing environmental demands. Awareness of this possibility may support more cautious decisions regarding continued exposure, recovery, return to activity, and the level of monitoring required.

Overall, the theoretical and practical contribution of this thesis lies in demonstrating the value of examining environmental stress across multiple levels of behaviour. Physiological measures characterise the perturbation imposed on the organism, while postural, manual, perceptual–motor, vehicle-control, and gaze-related measures provide complementary information about its behavioural consequences. Integrating these outcomes offers a more complete account of human functioning in extreme environments than considering physiological responses or task success alone.

General Limitations and Future Directions

Several limitations should be considered when interpreting the findings of this thesis. First, both experimental studies examined acute environmental exposure. The findings therefore cannot be directly generalised to prolonged or repeated exposure, acclimatisation, or chronic adaptation. Future studies should determine whether the patterns observed in postural control, perceptual–motor calibration, motor function, and visual exploration persist or change with longer or repeated exposure to environmental stress.

Second, the findings are specific to the populations and tasks examined. Participants were healthy adults, and the cold-water immersion study involved competent swimmers. In addition, the controlled laboratory tasks allowed standardised assessment but cannot fully reproduce the complexity and uncertainty of real-world environments. This is particularly relevant to simulated driving, where natural traffic, physical motion cues, and the consequences of errors were absent. Future studies should therefore include populations with different levels of environmental experience and examine perception and action in more naturalistic settings.

The experimental studies also examined different components of perception and action across two environmental stressors. Affordance perception, maximum action capabilities, calibration, and postural control were assessed during hypoxia, whereas manual function, simulated driving, and gaze behaviour were examined following cold-water immersion. Consequently, direct conclusions about whether hypoxia and cold exposure influence the same perceptual–motor processes cannot be made. Future research should integrate physiological, perceptual–motor, motor, and gaze-related measures within the same experimental design to clarify how different components of behaviour respond to environmental perturbation.

Specific methodological considerations also apply to the eye-tracking findings. The analysis primarily used global measures of visual exploration, which describe the spatial organisation of gaze but do not identify the specific sources of information sampled within the driving environment. Future studies should incorporate area-of-interest analyses to determine whether environmental stress changes gaze allocation towards lane boundaries, surrounding traffic, mirrors, road signs, vehicle controls, or other task-relevant features. More naturalistic driving conditions and integration of gaze with vehicle-control and physiological measures would further clarify the functional relevance of these changes.

Finally, the environmental stressors were examined separately, whereas real-world performance may involve multiple stressors acting simultaneously. Future studies should investigate combinations of environmental and organismic factors, including hypoxia, cold, fatigue, sleep deprivation, and physical exertion. Such approaches would help determine whether the selective and task-dependent responses observed in this thesis remain evident when individuals are required to perceive and act under more complex environmental conditions.

REFERENCES

BAGUE, Kévin; LAURENT, Éric. Depressive symptoms and affordance perception: The case of perceived reachability boundary. **Psychonomic Bulletin and Review**, v. 30, n. 4, 2023.

BARWOOD, Martin J.; CORBETT, Jo; WAGSTAFF, Christopher R. D. Habituation of the Cold Shock Response May Include a Significant Perceptual Component. **Aviation, Space, and Environmental Medicine**, v. 85, n. 2, p. 167–171, 1 fev. 2014.

BHARGAVA, Ayush *et al.* Can I Squeeze Through? Effects of Self-Avatars and Calibration in a Person-Plus-Virtual-Object System on Perceived Lateral Passability in VR. **IEEE Transactions on Visualization and Computer Graphics**, v. 29, n. 5, 2023.

BINGHAM, Geoffrey P.; PAGANO, Christopher C. The Necessity of a Perception-Action Approach to Definite Distance Perception: Monocular Distance Perception to Guide Reaching. **Journal of Experimental Psychology: Human Perception and Performance**, v. 24, n. 1, 1998.

BUJAS, Przemysław *et al.* Acute Effects of Combined Hypoxia and Fatigue on Balance in Young Men. **Applied Sciences (Switzerland)**, v. 14, n. 2, 2024.

BURTSCHER, Martin *et al.* **Extreme terrestrial environments: Life in thermal stress and hypoxia. A narrative review**. **Frontiers in Physiology**, 2018.

CASTELLANI, John W.; YOUNG, Andrew J. **Human physiological responses to cold exposure: Acute responses and acclimatization to prolonged exposure**. **Autonomic Neuroscience: Basic and Clinical**Elsevier B.V., , 1 abr. 2016.

CASTELLANI, John William; YOUNG, Andrew John. **Health and performance challenges during sports training and competition in cold weather**. **British Journal of Sports Medicine**, 2012.

CHEN, Wen Lin; SHIH, Yuh Chuan; CHI, Chia Fen. Hand and finger dexterity as a function of skin temperature, EMG, and ambient condition. **Human Factors**, v. 52, n. 3, 2010.

CHEUNG, S. S. **Advanced environmental exercise physiology**. *[S.l.: S.n.]*.

CHEUNG, Stephen S. *et al.* Changes in manual dexterity following short-term hand and forearm immersion in 10°c water. **Aviation Space and Environmental Medicine**, v. 74, n. 9, 2003.

CHEUNG, Stephen S. **Responses of the hands and feet to cold exposure**. **Temperature**, 2015.

CHROBOCZEK, Maciej *et al.* Acute Normobaric Hypoxia Lowers Executive Functions among Young Men despite Increase of BDNF Concentration. **International Journal of Environmental Research and Public Health**, v. 19, n. 17, 2022.

COPPEL, Jonny *et al.* **The physiological effects of hypobaric hypoxia versus normobaric hypoxia: A systematic review of crossover trials**. **Extreme Physiology and Medicine**, 2015.

COTTER, James D.; TIPTON, Michael J. **Moving in extreme environments: What's extreme and who decides? Extreme Physiology and Medicine**, 2014.

CROFT, James L.; BERTRAM, John E. A. Affordance boundaries are defined by dynamic capabilities of Parkour athletes in dropping from various heights. **Frontiers in Psychology**, v. 8, n. SEP, 2017.

CROWTHER, Rian H. *et al.* Exploration evoked by the environment is balanced by the need to perform in cricket spin bowling. **Psychology of Sport and Exercise**, v. 57, 2021.

CUTTING, James E.; PROFFITT, Dennis R. The minimum principle and the perception of absolute, common, and relative motions. **Cognitive Psychology**, v. 14, n. 2, 1982.

DAANEN, Hein A. M. Manual performance deterioration in the cold estimated using the wind chill equivalent temperature. **Industrial Health**, v. 47, n. 3, 2009.

DAANEN, Hein A. M.; VAN DE VLIERT, Evert; HUANG, Xu. Driving performance in cold, warm, and thermoneutral environments. **Applied Ergonomics**, v. 34, n. 6, 2003.

DAMLE, Samruddhi; BOOTSMA, Reinoud J.; ZAAL, Frank T. J. M. Perceiving the affordance of interceptability for another. **Frontiers in Psychology**, v. 16, 2025.

DAVIDS, Keith *et al.* **Movement systems as dynamical systems: The functional role of variability and its implications for sports medicine**. **Sports Medicine**, 2003.

DAVIDS, Keith. Principles of Motor Learning in Ecological Dynamics A comment on Functions of Learning and the Acquisition of Motor Skills (With Reference to Sport). **The Open Sports Sciences Journal**, v. 5, n. 1, p. 113–117, 13 set. 2012.

DAY, Brian M.; WAGMAN, Jeffrey B.; SMITH, Peter J. K. Perception of maximum stepping and leaping distance: Stepping affordances as a special case of leaping affordances. **Acta Psychologica**, v. 158, 2015.

DEBENHAM, M. I. B. *et al.* The effects of four hours of normobaric hypoxia on the vestibular control of balance. **Experimental Brain Research**, v. 242, n. 10, 2024.

DEBENHAM, Mathew I. B. *et al.* **Hypoxia and standing balance**. **European Journal of Applied Physiology**, 2021.

DEGACHE, Francis *et al.* Hypobaric versus normobaric hypoxia: Same effects on postural stability? **High Altitude Medicine and Biology**, v. 13, n. 1, 2012.

DEHAIS, Frédéric *et al.* Pilot Flying and Pilot Monitoring's Aircraft State Awareness During Go-Around Execution in Aviation: A Behavioral and Eye Tracking Study. **The International Journal of Aerospace Psychology**, v. 27, n. 1–2, p. 15–28, 3 abr. 2017.

DI STASI, Leandro L. *et al.* **Saccadic velocity as an arousal index in naturalistic tasks**. **Neuroscience and Biobehavioral Reviews**, 2013.

DICKS, Matt; BUTTON, Chris; DAVIDS, Keith. Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action. **Attention, Perception, & Psychophysics**, v. 72, n. 3, p. 706–720, abr. 2010.

DICKS, Matt; DAVIDS, Keith; BUTTON, Chris. Individual differences in the visual control of intercepting a penalty kick in association football. **Human movement science**, v. 29, p. 401–411, 1 mar. 2010.

DRUM, Scott N. *et al.* Acute effects of walking at moderate normobaric hypoxia on gait and balance performance in healthy community-dwelling seniors: A randomized controlled crossover study. **Archives of Gerontology and Geriatrics**, v. 67, 2016.

EDELMAN, G. M.; GALLY, J. A. Degeneracy and complexity in biological systems. **Proceedings of the National Academy of Sciences of the United States of America**, v. 98, n. 24, 2001.

ENANDER, Ann. Effects of moderate cold on performance of psychornotor and cognitive tasks. **Ergonomics**, v. 30, n. 10, 1987.

FAJEN, Brett R. Perceiving possibilities for action: On the necessity of calibration and perceptual learning for the visual guidance of action. **Perception**, 2005a.

FAJEN, Brett R. Calibration, information, and control strategies for braking to avoid a collision. **Journal of Experimental Psychology: Human Perception and Performance**, v. 31, n. 3, 2005b.

FAJEN, Brett R. Affordance-based control of visually guided action. **Ecological Psychology**, 2007.

FAJEN, Brett R.; RILEY, Michael A.; TURVEY, Michael T. Information, affordances, and the control of action in sport. **International Journal of Sport Psychology**, v. 40, n. 1, p. 79–107, 2009.

FALLA, Marika *et al.* **The effect of cold exposure on cognitive performance in healthy adults: A systematic review**. **International Journal of Environmental Research and Public Health**, 2021.

FRANCHAK, John; ADOLPH, Karen. Affordances as Probabilistic Functions: Implications for Development, Perception, and Decisions for Action. **Ecological Psychology**, v. 26, n. 1–2, 2014.

FRANCHAK, John M.; VAN DER ZALM, Dina J.; ADOLPH, Karen E. Learning by doing: Action performance facilitates affordance perception. **Vision Research**, v. 50, n. 24, 2010.

GATES, Deanna H.; DINGWELL, Jonathan B. The effects of neuromuscular fatigue on task performance during repetitive goal-directed movements. **Experimental Brain Research**, v. 187, n. 4, 2008.

GIBSON, Elanor; RADER, Nancy. Attention. The perceiver as performer. *In*: HALE, G.; LEWIS, M. (Orgs.). **Attention and Cognitive Development**. New York: Plenum., 1979. p. 1–21.

GIBSON, James J. **The perception of the visual world**. Boston: Houghton Mifflin Company, 1950.

GIBSON, James J. The Theory of Affordances" The Ecological Approach to Visual Perception. **The Ecological Approach to Visual Perception**, 1979a.

GIBSON, James J. The Ecological Approach to Visual Perception. *In*: 1979b.

GIESBRECHT, G. G. Prehospital treatment of hypothermia. **Wilderness and Environmental Medicine**, v. 12, n. 1, 2001.

HALSEY, Lewis G.; STROUD, Mike A. **100 years since Scott reached the Pole: A century of learning about the physiological demands of Antarctica**. **Physiological Reviews**, 2012.

HAYHOE, Mary; BALLARD, Dana. **Eye movements in natural behavior**. **Trends in Cognitive Sciences**, 2005.

HAYHOE, Mary M. *et al.* Visual memory and motor planning in a natural task. **Journal of Vision**, v. 3, n. 1, 2003.

HEUVELMANS, Pieter *et al.* Relationships Between Task Constraints, Visual Constraints, Joint Coordination and Football-Specific Performance in Talented Youth Athletes: An Ecological Dynamics Approach. **Perceptual and Motor Skills**, v. 131, n. 1, p. 161–176, 10 fev. 2024.

HIGUCHI, Takahiro *et al.* Visual Estimation of Spatial Requirements for Locomotion in Novice Wheelchair Users. **Journal of Experimental Psychology: Applied**, v. 10, n. 1, 2004.

HOLMQVIST, Kenneth *et al.* **Eye tracking : a comprehensive guide to methods and measures**. oxford: Oxford University Press, 2011.

HORAK, Fay B. Postural orientation and equilibrium : what do we need to know about neural control of balance to prevent falls ? **Age and Ageing**, v. 35, n. SUPPL.2, p. 7–11, 2006.

HOSPODAR, Christina; FRANCHAK, John; ADOLPH, Karen. Performance variability and affordance perception: practice effects on perceptual judgments for walking versus throwing. **Experimental Brain Research**, v. 241, n. 8, 2023.

IMAMURA, Ritsuko *et al.* Manual performance in cold conditions while wearing NBC clothing. **Ergonomics**, v. 41, n. 10, 1998.

JACOBS, David M.; MICHAELS, Claire F. Direct Learning. **Ecological Psychology**, v. 19, n. 4, p. 321–349, 21 set. 2007.

JAYASWAL, R.; SIVADAS, P.; MISHRA, SS. Health and performance of military personnel in cold climatic environment of the western himalayas. **Medical Journal Armed Forces India**, v. 57, n. 4, p. 322–325, out. 2001.

JIANG, Yang; MARK, Leonard S. The effect of gap depth on the perception of whether a gap is crossable. **Perception & Psychophysics**, v. 56, n. 6, p. 691–700, nov. 1994.

JOHANSSON, Gunnar. Visual perception of biological motion and a model for its analysis. **Perception & Psychophysics**, v. 14, n. 2, 1973.

JONES, Douglas *et al.* Evaluation of Three Field Rewarming Techniques During Cold Weather Military Training. **Wilderness & Environmental Medicine**, v. 31, n. 3, p. 285–290, 1 set. 2020.

KONSTANTOPOULOS, Panos; CHAPMAN, Peter; CRUNDALL, David. Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore drivers' eye movements in day, night and rain driving. **Accident Analysis and Prevention**, v. 42, n. 3, 2010.

KREDEL, Ralf *et al.* Eye-tracking technology and the dynamics of natural gaze behavior in sports: A systematic review of 40 years of research. **Frontiers in Psychology**, v. 8, n. OCT, 2017.

LAND, M. F.; LEE, D. N. Where we look when we steer. **Nature**, v. 369, n. 6483, 1994.

LAND, Michael F. Eye movements and the control of actions in everyday life. **Progress in Retinal and Eye Research**, v. 25, n. 3, p. 296–324, 2006.

LAND, Michael F.; HAYHOE, Mary. In what ways do eye movements contribute to everyday activities? *In*: 2001.

LAND, Michael F.; MCLEOD, Peter. From eye movements to actions: Batsmen hit the ball. **Nature Neuroscience**, v. 3, n. 12, 2000.

LAPPI, Otto. **Eye movements in the wild: Oculomotor control, gaze behavior & frames of reference**. **Neuroscience and Biobehavioral Reviews**Elsevier Ltd, , 1 out. 2016.

LEE, Dn; LISHMAN, Jr. Vision - The most efficient Source of Proprioceptive Information for balance control. **Journal of Human Movement Studies**, v. 18, n. 1A, p. 83–94, 1975.

LIN, Lisa P. Y.; PLACK, Christopher J.; LINKENAUGER, Sally A. The Influence of Perceptual-Motor Variability on the Perception of Action Boundaries for Reaching in a Real-World Setting. **Perception**, v. 50, n. 9, 2021.

MÄKINEN, Tiina M. *et al.* Effect of repeated exposures to cold on cognitive performance in humans. **Physiology and Behavior**, v. 87, n. 1, 2006.

MÄKINEN, Tiina M. Human cold exposure, adaptation, and performance in high latitude environments. **American Journal of Human Biology**, v. 19, n. 2, 2007.

MALLE, Carine *et al.* Working memory impairment in pilots exposed to acute hypobaric hypoxia. **Aviation Space and Environmental Medicine**, v. 84, n. 8, 2013.

MANN, Derekt Y. *et al.* Perceptual-cognitive expertise in sport: A meta-analysis. **Journal of Sport and Exercise Psychology**, v. 29, n. 4, 2007.

MARK, Leonard S. Eyeheight-Scaled Information About Affordances: A Study of Sitting and Stair Climbing. **Journal of Experimental Psychology: Human Perception and Performance**, v. 13, n. 3, 1987.

MARK, Leonard S. *et al.* What an Actor Must Do in Order to Perceive the Affordance for Sitting. **Ecological Psychology**, v. 2, n. 4, 1990.

MARRAO, Claudia *et al.* Physical and cognitive performance during long-term cold weather operations. **Aviation Space and Environmental Medicine**, v. 76, n. 8, 2005.

MARTIN, Kristy *et al.* **The Impact of Environmental Stress on Cognitive Performance: A Systematic Review**. **Human Factors**, 2019.

MAZZEO, Robert S. **Physiological responses to exercise at altitude: An update**. **Sports Medicine**, 2008.

MCMORRIS, Terry *et al.* Neuroscience and Biobehavioral Reviews Effect of acute hypoxia on cognition : A systematic review and meta-regression analysis. **Neuroscience and Biobehavioral Reviews**, v. 74, 2017.

MCMORRIS, Terry *et al.* **Effect of acute hypoxia on cognition: A systematic review and meta-regression analysis**. **Neuroscience and Biobehavioral Reviews**, 2017.

MICHAELS, Claire; CARELLO, Claudia. Direct Perception. **New Jersey, Englewood Cliffs: Prentice-Hall. Moggridge, B. (1993). Design by storytelling. Applied Ergonomics**, v. 24, 1 jan. 1981.

MILLET, Grégoire P.; FAISS, Raphael; PIALOUX, Vincent. Point: Counterpoint: Hypobaric hypoxia induces/does not induce different responses from normobaric hypoxia. **Journal of Applied Physiology**, v. 112, n. 10, p. 1783–1784, 15 maio 2012.

MORTON, William J. *et al.* Manual Dexterity in Open-Water Wetsuited Swimmers: A Cohort Crossover Study. **International Journal of Sports Physiology and Performance**, v. 20, n. 2, 2025.

O'BRIEN, Catherine *et al.* Dietary tyrosine benefits cognitive and psychomotor performance during body cooling. **Physiology & Behavior**, v. 90, n. 2–3, p. 301–307, fev. 2007.

OCHI, Genta *et al.* Hypoxia-induced lowered executive function depends on arterial oxygen desaturation. **Journal of Physiological Sciences**, v. 68, n. 6, 2018.

OKSA, Juha. **Neuromuscular performance limitations in cold. International journal of circumpolar health**, 2002.

ORYSIAK, Joanna; MŁYNARCZYK, Magdalena; IRZMAŃSKA, Emilia. The Impact of Protective Gloves on Manual Dexterity in Cold Environments—A Pilot Study. **International Journal of Environmental Research and Public Health**, v. 19, n. 3, 2022.

ORYSIAK, Joanna; MŁYNARCZYK, Magdalena; IRZMAŃSKA, Emilia. The effect of exposure to cold on dexterity and temperature of the skin and hands. **International Journal of Occupational Safety and Ergonomics**, v. 30, n. 1, 2024.

PAGANO, Christopher C.; BINGHAM, Geoffrey P. Comparing Measures of Monocular Distance Perception: Verbal and Reaching Errors Are Not Correlated. **Journal of Experimental Psychology: Human Perception and Performance**, v. 24, n. 4, 1998.

PETERKA, R. J.; HEALTH, Oregon. Sensorimotor Integration in Human Postural Control. p. 1097–1118, 2002.

PIGHIN, Stefania *et al.* Decision making under hypoxia: Oxygen depletion increases risk seeking for losses but not for gains. **Judgment and Decision Making**, v. 7, n. 4, 2012.

PIJPERS, J. R.; OUDEJANS, Raôul R. D.; BAKKER, Frank C. Changes in the perception of action possibilities while climbing to fatigue on a climbing wall. **Journal of Sports Sciences**, 2007.

POJSKIĆ, Haris *et al.* Acute Exposure to Normobaric Hypoxia Impairs Balance Performance in Sub-elite but Not Elite Basketball Players. **Frontiers in Physiology**, v. 12, 2021.

RAMENZONI, Verónica C. *et al.* Perceiving action boundaries: Learning effects in perceiving maximum jumping-reach affordances. **Attention, Perception, & Psychophysics**, v. 72, n. 4, p. 1110–1119, maio 2010.

RAMÍREZ-DELACRUZ, María *et al.* **Effects of Acute Hypoxic Exposure in Simulated Altitude in Healthy Adults on Cognitive Performance: A Systematic Review and Meta-Analysis**. **Biology**, 2024.

RANDERATH, Jennifer *et al.* Is This Within Reach? Left but Not Right Brain Damage Affects Affordance Judgment Tendencies. **Frontiers in Human Neuroscience**, v. 14, 2021.

RANDERATH, Jennifer; FREY, Scott H. Diagnostics and training of affordance perception in healthy young adults-implications for post-stroke neurorehabilitation. **Frontiers in Human Neuroscience**, v. 9, n. JAN2016, 2016.

RAY, Matthew *et al.* The Combined Effect of Cold and Moisture on Manual Performance. **Human Factors**, v. 60, n. 1, 2018.

RAYNER, Keith. Eye Movements in Reading and Information Processing: 20 Years of Research. **Psychological Bulletin**, v. 124, n. 3, 1998.

RENBERG, Julie *et al.* The effect of mild whole-body cold stress on isometric force control during hand grip and key pinch tasks. **Journal of Thermal Biology**, v. 89, 2020.

ROSADO, Hugo *et al.* Can two multimodal psychomotor exercise programs improve attention, affordance perception, and balance in community dwellings at risk of falling? A randomized controlled trial. **BMC Public Health**, v. 21, 2021.

SCHÄRLI, A. M. *et al.* The influence of gaze behaviour on postural control from early childhood into adulthood. **Gait and Posture**, p. 78–84, 2012.

SEIFERT, Ludovic *et al.* Coordination Pattern Variability Provides Functional Adaptations to Constraints in Swimming Performance. **Sports Medicine**, v. 44, n. 10, 2014.

SEIFERT, Ludovic *et al.* Neurobiological degeneracy: A key property for functional adaptations of perception and action to constraints. **Neuroscience & Biobehavioral Reviews**, v. 69, p. 159–165, out. 2016.

SEIFERT, Ludovic *et al.* Understanding constraints on sport performance from the complexity sciences paradigm: An ecological dynamics framework. **Human Movement Science**, v. 56, 2017.

SEIFERT, Ludovic *et al.* The perception of nested affordances: An examination of expert climbers. **Psychology of Sport and Exercise**, v. 52, 2021.

SEIFERT, Ludovic; BUTTON, Chris; DAVIDS, Keith. **Key properties of expert movement systems in sport: An ecological dynamics perspective**. **Sports Medicine**, 2013.

STOFFREGEN, Thomas A. *et al.* Perceiving affordances for another person's actions. **Journal of Experimental Psychology: Human Perception and Performance**, 1999a.

STOFFREGEN, Thomas A. *et al.* Postural Stabilization of Looking. **Journal of Experimental Psychology: Human Perception and Performance**, v. 25, n. 6, p. 1641–1658, 1999b.

STOFFREGEN, Thomas A. Affordances and Events. **Ecological Psychology**, v. 12, n. 1, p. 1–28, fev. 2000.

TATLER, Benjamin W. *et al.* Eye guidance in natural vision: Reinterpreting salience. **Journal of Vision**, v. 11, n. 5, 2011.

THOMAS, Brandon J.; HAWKINS, Matthew M.; NALEPKA, Patrick. Perceiver as polar planimeter: Direct perception of jumping, reaching, and jump-reaching affordances for the self and others. **Psychological Research**, v. 82, n. 4, 2018.

THOMAS, Robert Joseph *et al.* Nocturnal hypoxia exposure with simulated altitude for 14 days does not significantly alter working memory or vigilance in humans. **Sleep**, v. 30, n. 9, 2007.

TIPTON, M. J. Environmental extremes: origins, consequences and amelioration in humans. **Experimental Physiology**, v. 101, n. 1, 2016.

TIPTON, M. J. *et al.* Cold water immersion: kill or cure? **Experimental Physiology**, v. 102, n. 11, 2017.

TIPTON, Michael J. *et al.* Habituation of the metabolic and ventilatory responses to cold-water immersion in humans. **Journal of Thermal Biology**, v. 38, n. 1, 2013.

TIPTON, Mike. Cold water immersion: sudden death and prolonged survival. **Lancet**, v. 362 Suppl, 2003.

VAN ANDEL, Steven; COLE, Michael H.; PEPPING, Gert Jan. A systematic review on perceptual-motor calibration to changes in action capabilities. **Human Movement Science**, v. 51, 2017.

VAUCLIN, Pierre *et al.* The effect of experience on the perception of affordances for aperture crossing in cycling. **Psychology of Sport and Exercise**, v. 74, 2024.

VEGAS, Colin; LAURENT, Éric. Mood Influences the Perception of the Sitting Affordance. **Attention, Perception, & Psychophysics**, v. 84, n. 1, p. 270–288, 14 jan. 2022.

VICKERS, Joan. **Perception, cognition and decision training: The quiet eye in action**. *[S.l.: S.n.]*.

VILAR, Lus *et al.* The role of ecological dynamics in analysing performance in team sports. **Sports Medicine**, v. 42, n. 1, 2012.

VIRUÉS-ORTEGA, Javier *et al.* **Neuropsychological functioning associated with high-altitude exposure**. **Neuropsychology Review**, 2004.

VU, Alexandre *et al.* Multiple Players Tracking in Virtual Reality: Influence of Soccer Specific Trajectories and Relationship With Gaze Activity. **Frontiers in Psychology**, v. 13, 2022.

WAGMAN, Jeffrey B.; BAI, Jiuyang; SMITH, Peter J. K. Nesting in perception of affordances for stepping and leaping. **Attention, Perception, and Psychophysics**, v. 78, n. 6, p. 1771–1780, 1 ago. 2016.

WAGMAN, Jeffrey B.; TAYLOR, Kona R. Perceiving affordances for aperture crossing for the person-plus-object system. **Ecological Psychology**, v. 17, n. 2, 2005.

WAGNER, Linsey S. *et al.* Hypoxia-induced changes in standing balance. **Aviation Space and Environmental Medicine**, v. 82, n. 5, 2011.

WAKABAYASHI, Hitoshi; OKSA, Juha; TIPTON, Michael J. Exercise performance in acute and chronic cold exposure. **The Journal of Physical Fitness and Sports Medicine**, v. 4, n. 2, p. 177–185, 2015.

WALLACE, Phillip J. *et al.* Effects of skin and mild core cooling on cognitive function in cold air in men. **Physiological Reports**, v. 11, n. 24, 2023.

WARD, Michael P. Everest 1953, first ascent: A clinical record. **High Altitude Medicine and Biology**, v. 4, n. 1, 2003.

WARREN, Jr *et al.* Optic flow is used to control human walking. **Nature Neuroscience**, v. 4, n. 2, 2001.

WARREN, William H. Perceiving affordances: Visual guidance of stair climbing. **Journal of Experimental Psychology: Human Perception and Performance**, v. 10, n. 5, 1984.

WARREN, William H. The dynamics of perception and action. **Psychological Review**, 2006.

WARREN, William H.; WHANG, Suzanne. Visual Guidance of Walking Through Apertures: Body-Scaled Information for Affordances. **Journal of Experimental Psychology: Human Perception and Performance**, v. 13, n. 3, 1987.

WEST, Charles K.; GIBSON, James J. The Senses Considered as Perceptual Systems. **Journal of Aesthetic Education**, v. 3, n. 1, p. 142, 1969.

WEST, John *et al.* **HIGH ALTITUDE MEDICINE AND PHYSIOLOGY, Fifth edition**. *[S.l.: S.n.]*.

WHEELOCK, Courtney E. *et al.* Whole-body active heating does not preserve finger temperature or manual dexterity during cold-water immersion. **Undersea and Hyperbaric Medicine**, p. 253–260, 1 abr. 2020.

WHITACRE, James M. Degeneracy: A link between evolvability, robustness and complexity in biological systems. **Theoretical Biology and Medical Modelling**, v. 7, n. 1, 2010.

WITHAGEN, Rob; MICHAELS, Claire F. The role of feedback information for calibration and attunement in perceiving length by dynamic touch. **Journal of Experimental Psychology: Human Perception and Performance**, v. 31, n. 6, 2005.

WITHAGEN, Rob; MICHAELS, Claire F. **Transfer of calibration between length and sweet-spot perception by dynamic touch**. **Ecological Psychology**, 2007.

WOOLLACOLT, Marjorie; DEBÚ, Beltina; MOWATL, Marilyn. **Neuro muscular control of posture in the infant and child Is Vision Dominant.pdf**. , 1987.

YU, Yawen; STOFFREGEN, Thomas A. Postural and locomotor contributions to affordance perception. **Journal of Motor Behavior**, v. 44, n. 5, 2012.

ZANDER, Joanna; MORRISON, James. Effects of pressure, cold and gloves on hand skin temperature and manual performance of divers. **European Journal of Applied Physiology**, v. 104, n. 2, p. 237–244, 28 set. 2008.