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Fechner Day, 2024

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IIT Kanpur, India

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Preface

We welcome all the readers to the 40th Annual Meeting of the International Society for Psychophysics (ISP). The conference received many substantial contributions covering various areas of Psychophysics. The work will be presented in the form of talks and posters.

The ideas of Gustav Theodore Fechner has influenced generations of researchers, teaching them to think analytically and a commitment towards more quantifiable measurement of mental processes. His data driven approach to understand perceptual experiences played a pivotal role in bridging the gap between philosophy of perception and science of perception, laying groundwork for modern psychology and cognitive science. His influence can be seen in contemporary research on perception, decision making, and the scientific exploration of consciousness, which continues to build on his early insights. Fechner day is our way of acknowledging his immense contribution to the field.

On behalf of the organizing team of Fechner Day 2024 and ISP, we welcome everyone to IIT Kanpur and wish you a fruitful and pleasant meeting. For those who have traveled from outside India, we wish you an interesting and enjoyable time in India. We thank everyone for making it to IIT Kanpur this year. Thanks to Tal for arranging a special symposium. A special thanks to the President of ISP, Prof. William Stine and other members of the executive committee of ISP.

Narayanan Srinivasan and Devpriya Kumar
October 2024, IIT Kanpur, India

Fechner Day, 2024

Scientific Program and Meeting Schedule

Note: All plenary, theme, and poster sessions will take place in PBCEC Class Room and Lounge, IIT Kanpur. Day 1 of the conference, i.e., 7th October, will be an online symposium.

Day 1 (Monday, 7th October)

	Online Symposium - The Human Biofield, Psychophysics and Healing (Chair: Tal Dotan Ben-Soussan)
17.30-18.30	REGISTRATION High Tea
18.30-19.00	Inauguration (PBCC Room and Online)
19.00-19.15	Tal Dotan Ben-Soussan Symposium Introduction: Exploring the Frontiers of Consciousness, Healing, and the Biofield
19.15-19.45	Patrizio Paoletti and Tal Dotan Ben-Soussan Re-narrating our-selves in light of Sphere Model of Consciousness, EEG synchronization and health
19.45-20.15	Shamini Jain Biofield Science and Healing – Emerging Research and Implications for Psychophysics and Psychoneuroimmunology
20.15-20.45	Shamini Jain, Chloe Tanega, Lorna Ciccone, & Cheryl Ritenbaugh Biofield Based Sound Healing for Anxiety: Current research and further directions
20.45-21.15	Fabienne Picard Epilepsy and ecstatic experiences: The role of the insula
21.15-21.45	Konstantin Korotkov Biofield and Health - conceptual ideas and practical approach
21.45-22.15	Helané Wahbeh Energy medicine and how we see it: Explorations into the mechanism of biofield therapies

Day 2 (Tuesday, 8th October)

	S1 Keynote (Chair: Devpriya Kumar)
09.30-10.30	Timothy Hubbard Naïve physics, phenomenal causality, and psychophysics
10.30-11.00	Coffee/Tea
	S2 Talks (Chair: Nisheeth Srivastava)
11.00-11.30	Yaniv Mama Odor-pitch interaction; cross-modal integration between sound and odor
11.30-12.00	Rahul Kumar Ray Towards multimodal Steven's power law using neural coding
12.00-12.30	Oria Pitam Pupillary light response in vertical and horizontal fields of view
12.30-13.00	Khushi Kaur Juneja Anthropogenic and natural soundscapes: How environment colors our subjective experience of time
13.00-14.00	Lunch
	S3 Talks (Chair: Anuj Shukla)
14.00-14.30	Anand Prasad Preceding temporal context enhances temporal resolution
14.30-15.00	Hannah Plueckebaum Neural correlates of time of day effects on inhibitory control
15.00-15.30	Alexander Bulajic The endless global precedence effect: Behavioural dynamics between global precedence and the fast same effect
15.30-16.00	Coffee/Tea
16.00-17.00	**Poster Session**
17.00-17.30	**Business Meeting**

Day 2 (Tuesday, 8th October) - Poster Session (16.00-17.00)

Venue: PBCEC Lounge

Temporal Perception and Delay: Mechanisms of Distortion	Jahanvi Mittal
Slower temporal productions in meditation-like states	Michele Pellegrino
Variance of temporal context influences temporal integration	Ramya Mudumba
SARS-CoV-2 during pregnancy: Prematurity and olfactory response in newborns	Rosana Tristao
Investigating the role of repetition suppression in Temporal oddball effect	Shashwat Mani & Spandan Raha
Do you see an object to use it or hold it: Role of structural and functional actions on object processing	Tanvi Padia
Visual Global and Local Processing in the Broader Autism Phenotype depends on the Stimulus Material	Hannah Plueckebaum

Day 3 (Wednesday, 9th Oct)

Wednesday, 9th October 2024

	S1 Talks (Chair: Amrendra Singh)
09.00-09.30	Ankita Sengupta A double dissociation between neural mechanisms of reward-driven sensory and decisional selection
09.30-10.00	Suraj Kumar Time course of immediate Spatial cuing after the initial display does not influence change detection performance in natural scenes
10.00-10.30	Swagata Halder Role of the right parietal cortex in mediating subcomponents of the attentional blink
10.30-11.00	Coffee/Tea
	S2 Keynote (Chair: Yaniv Mama)
11.00-12.00	Yoshitaka Nakajima Minimal rhythm: How two neighboring time intervals marked by sound onsets are perceived
	S2 Talks (Chair: Yaniv Mama)
12.00-12.30	Jessica Das Motion-Induced Blindness: A Comparative Analysis of Photopic vs. Scotopic Vision
12.30-13.00	Georgia Gempler and Emily Komersk The effects of contrast on motion induced blindness and perceptual-filling in
13.00-14.00	Lunch
	S3 Talks (Chair: William Stine)
14.00-14.30	Laís Muntini The Environment as a Factor: Investigating the impact of the environment on cognition with VR
14.30-15.00	Mounika Dasa Role of Anticipation in Improving Visuo-Proprioceptive Integration and Enhancing User Experience in Virtual Reality

15.00-15.30	Coffee/Tea
	S3 Keynote (Chair: William Stine)
15.30-16.30	Diana Kornbrot Open Science and psychophysics: Tools to study the mind
16.30-17.00	Concluding Ceremony

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Abstracts for Online Symposium

Symposium Introduction: Exploring the Frontiers of Consciousness, Healing and the Biofield

Tal Dotan Ben-Soussan

Research Institute for Neuroscience, Education and Didactics (RINED), Patrizio Paoletti Foundation for Development and Communication, Italy

Psychophysics, as first established by Gustav Theodor Fechner could be defined as the science of the relations between body and mind, or between physical and phenomenal worlds. In this symposium, we explore these connections, particularly in the context of health and healing. This symposium brings together recent research that bridges neuroscience, psychophysics, psychoneuroimmunology, and biofield science to explore the relationships between consciousness, health, and healing. The presentations span diverse yet interconnected topics, from the neurophenomenological aspects of healing the self to the emerging science of biofields and their implications for mental and physical health. By examining phenomena such as EEG synchronization, energy medicine, sound healing, and mystical experiences linked to epilepsy, this symposium offers a holistic view of health and well-being. Researchers will present novel insights into the mechanisms underlying biofield therapies, impact of words, the way we speak and sound on anxiety and wellbeing, and the potential of electrophotonic imaging in diagnosing and treating various conditions. Together, the symposium may expand some conventional assumptions regarding the duality of body and mind in medicine and psychology, proposing innovative approaches for fostering resilience, healing, and a deeper understanding of the self and consciousness.

Re-Narrating Our-Selves in Light of Sphere Model of Consciousness, EEG Synchronization, and Health

Patrizio Paoletti and Tal Dotan Ben-Soussan

Research Institute for Neuroscience, Education and Didactics (RINED), Patrizio Paoletti Foundation for Development and Communication, Italy

How can we define health and healing? Autobiographical memory is composed of a stratification of perceptions, through molecular processes that have only been investigated partially. For example, we know that memory formation is modulated among others by several mood-related neurotransmitters. These processes can be metaphorically represented within the Sphere Model of Consciousness (SMC) by the encounter between the time and emotion axes. Memories record a subjective, partial view of experience, and that perception itself is constantly mediated by interpretation. This is supported by the temporal gap between sensory perception and consciousness of a stimulus, which in some cases can reach up to half a second. We also know that memories are incessantly used by the brain for predictive activity, and that this activity influences sensory perception. Perception is a receptive rather than a passive process: if the stratification of memories constitutes the past in the SMC, projection represents the future. As an experience becomes more distant in time and space, it becomes increasingly abstract and subject to further elaboration. This greater level of abstraction comes with greater variability of interpretation. In this context, from a neurophenomenological perspective, the Narrative Self is considered as a self-image built through autobiographical memories and projections into the future; it involves awareness of personal identity and its continuity through time, as well as conceptual contents. On the other hand, the Minimal Self emerges from the awareness of a situated living body as a sensorimotor unit that enables selfhood in the physical world in the "here and now", has a short temporal extension, and is endowed with a sense of action, property, and first person non-conceptual content. Based on the SMC, we specified the addition of a third state, called Overcoming of the Self, in which all sense of self disappears yet subjective experiences are still able to be experienced and eventually re-interpreted, regenerated. In the current talk, we will discuss the importance of re-interpretation and training-induced changes in EEG and the biofield for building a more resilient self and healing, though the active process of detached presence, attention and will.

Biofield Science and Healing - Emerging Research and Implications for Psychophysics and Psychoneuroimmunology

Shamini Jain

Department of Family Medicine, UC San Diego and Consciousness and Healing Initiative, La Jolla, CA

Biofield science (the study of fields of energy and information that guide the homeodynamic regulation of a living organism) is a broad and emerging area of research, with provocative studies suggesting that biofield perturbations may have a significant impact on health and wellbeing. Areas of biofield research are as vast as examining the effects of bioelectromagnetic devices on human health, exploring biofield emanations of humans related to emotional and mental states (including the analysis of the electrodynamics of heart, brain and body signals as well as quantifications in biophoton emission), investigating electrical signaling across cellular membranes as it relates to neural growth and cancer metastasis, and even human-to–human healing studies where healing practitioners purport to sense and shift biofields around the human body to foster a salutogenic response.

This presentation will provide an overview of biofield science as it relates to healing, drawing upon peer-reviewed, published clinical and preclinical studies with biofield healing practitioners, to explore the potential role of biofield regulation in mitigating pain, fatigue, post-traumatic stress and other mental health conditions. Peer reviewed, published studies examining effects of biofield healing on physiology (including hormone and immune function) from both randomized controlled clinical trials and placebo-controlled studies with cells and animals that demonstrate impact of human biofields on cancer cell growth and metastasis will also be presented. Challenges to this emerging area of research, and the potential role of biofield science in extending understandings in both the fields of psychophysics and psychoneuroimmunology, will be discussed.

Biofield-Based Sound Healing for Anxiety: Current Research and Further Directions

Shamini Jain*, Chloe Tanega*., Lorna Ciccone*+, Cheryl Ritenbaugh*

+Department of Family Medicine, UC San Diego

**Consciousness and Healing Initiative, La Jolla, CA*

The importance and use of sound for conscious connection and healing has been written about and practiced in numerous indigenous cultures across the globe for centuries. However, the scientific investigation of sound for fostering healing and wellbeing is just beginning, and exploring the impact of sound on health from a biofield perspective is not yet represented in the scientific literature.

This presentation highlights recently published and ongoing research investigating claims made by modern sound healing practitioners on sound, the biofield and health, as well as reports on recent feasibility and randomized controlled trial research investigating the effects of a particular type of sound healing practice (Biofield Tuning or BT) on anxiety and wellbeing in persons meeting criteria for Generalized Anxiety Disorder (GAD).

Our initial study with three BT practitioners and 10 participants, found no evidence for inter-rater reliability across practitioners of biofield perturbations related to previous traumatic insults ($p > .05$ in all cases). Implications of this negative finding in inter-rater reliability of biofield assessment across practitioners will be discussed in the context of integrative health practice.

A separate feasibility study, aimed at investigating the claim that that BT may reduce anxiety even when BT was performed virtually at a distance, was conducted with 5 BT practitioners and 15 participants meeting criteria for GAD. Each participant was given a weekly BT session for three consecutive weeks. Quantitative analysis with gold-standard self-report questionnaires showed that BT significantly reduced anxiety, negative affect, and stress ($p<.05$). In addition, significant reductions were found in negative affect language in spoken word data ($p <.05$ in all cases). Qualitative data from participant interviews revealed themes of surprise regarding BT practitioner accuracy in determining previous events which they had not verbally reported, as well sensing sensations and hearing changes in tuning fork sounds. Participants also described a shift in their perception of self and relationship with anxiety, corroborating with quantitative data. As feasibility data indicated favourability to conduct a more robust controlled study, our current randomized controlled trial now investigates distant, virtually conducted BT compared to a health education control group in 100 participants who meet criteria for GAD, where quantitative data on psychological functioning as well as spoken language and fecal microbiome changes are being examined. Results from this emerging data will be shared, and implications for sound healing for mental health and the role of the biofield perspective in examination of sound healing, will be discussed.

Epilepsy and Ecstatic Experiences: The Role of the Insula

Fabienne Picard

Department of Clinical Neurosciences, University Hospitals and Medical School of Geneva

Epilepsy has always provided a unique opportunity to get a better understanding of complex cognitive functions. A rare form of epilepsy has come to be known as "ecstatic epilepsy" and shares several key characteristics with mystical experiences, as defined by the American psychologist William James. Drawing on her long experience as a clinician (and a researcher), Dr. Picard will offer us some key insights on the brain correlates of these ecstatic and mystical-type experiences, not unlike what can occur in certain states of meditation. She will outline her hypothesis about the role of the insula and the extinction of "interoceptive surprise" in allowing an ecstatic quality of the experience of the world to emerge. A few patients filled in a MEQ30 questionnaire for mystical experience. During a pre-surgical evaluation of their epilepsy with intracerebral electrodes, the ecstatic experience could be reproduced or induced in several patients with epilepsy through electrical stimulations of the dorsal anterior insula. In a pilot study in 3 of them, a tendency to increased heart rate variability could be shown during the sequences comprising (2 to 5 second-) stimulations with ecstatic experiences compared to control sequences comprising stimulations without ecstatic experiences.

Biofield and Health - Conceptual Ideas and Practical Approach

Konstantin Korotkov

St. Petersburg University of Informational Technologies, Mechanics and Optics and St. Petersburg Research institute of Physical Activity and Sport.

Electrophotonic Imaging (EPI), previously called Gas DischargeVisualization technique (GDV), is a breakthrough beyond Kirlian photography for direct, real-time viewing of the human energy system. This technology allows one to capture by a special camera the physical, emotional, mental, and spiritual energy emanating to and from an individual, plants, liquids, powders, inanimate objects and analyze it via the Internet with a powerful software based on a server, which allows researcher and client to see imbalances that may be influencing an individual's well-being greatly facilitating the diagnosis of the cause of any existing imbalances showing the area of the body and the organ systems involved. One of the most significant benefits to date is the ability to do "real-time" measurements of various treatments for such conditions as cancer to determine which is the most appropriate for the client. The incredible implications for diagnosing and treating physical, emotional, mental, and spiritual needs with applications in medicine, psychology, sound therapy, biophysics, genetics, forensic science, agriculture, ecology, etc., have been developed.

Energy Medicine and How We See It: Explorations into the Mechanism of Biofield Therapies

Helané Wahbeh

Institute of Noetic Sciences, USA

Introduction: The term "energy medicine," also known as biofield therapy, refers to healing modalities that manipulate or channel subtle energies associated with the body. Increasing research demonstrates that energy medicine yields positive outcomes for various conditions such as pain, depression, and quality of life. The Institute of Noetic Sciences (IONS) has conducted extensive research on these modalities, exploring their underlying mechanisms. This presentation will provide a foundation for understanding the field's evolution and significance by offering foundational definitions and historical context.

Methods: The presentation will proceed with a detailed review of completed studies conducted by IONS. Specific examples include rigorous investigations into the effects of energy medicine on participants with chronic pain and wrist pain, as well as studies evaluating the impact of Reiki sessions administered by Reiki Masters. The methodologies employed in these studies include measurements of primary pain outcomes, heart rate variability, environmental perceptions, and data from quantum noise generators.

Results: One notable study involving energy medicine practitioners and participants with chronic and wrist pain reported significant improvements in the primary pain outcome. Furthermore, there were notable shifts in heart rate variability, indicating greater parasympathetic activation. Additional findings included changes in the water treated by the practitioners and distinctive quantum noise generator data compared to control sessions. In another study, Reiki Masters administered 30-minute sessions to 40 participants, resulting in significant improvements in overall well-being. This study also recorded changes in the environment as perceived by skilled observers during the sessions.

Conclusions: The findings from these studies suggest that energy medicine or biofield therapy may have beneficial effects on pain relief and overall well-being. The observed physiological and environmental changes provide intriguing insights into the potential underlying mechanisms of these therapies.

Abstracts for Keynote Talks

Keynote 1 - Naïve Physics, Phenomenal Causality, and Psychophysics

Timothy L. Hubbard

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Abstract

Studies in naïve physics (i.e., how observers untutored in Newtonian physics understand and explain the operation of a physical system) and in phenomenal causality (i.e., the attribution of causality and agency to elements of a physical system) address an observer's perception and understanding of the operation of physical systems. Findings regarding naïve impetus theory (from naïve physics) and the launching effect (from phenomenal causality) suggest many observers believe in a pre-Newtonian concept of impetus (i.e., a force imparted to a target by contact with another object and that dissipates with subsequent motion of the target after contact is terminated). However, impetus is not an actual physical force, and properties ascribed to impetus do not describe any known physical force. The impetus notion is not consistent with Newton's First Law of Motion, and empirical findings suggestive of causal asymmetry, force asymmetry, and force-resistance asymmetry related to impetus are not consistent with Newton's Third Law of Motion. These findings challenge previous claims that causality is perceived in the launching effect, and it is suggested that observers use the impetus notion as a heuristic to predict target behavior; even though an impetus notion is physically incorrect, it provides approximately correct predictions regarding the behavior of a launched target (e.g., the target will move a short distance and then stop, and the target will move farther before stopping if it is launched [pushed] with more force). Study of the impetus notion demonstrates that the psychology (i.e., mental representation) of how physical systems operate (even a system as simple as one object colliding with another object in the launching effect) does not match the physics of how physical systems operate. As a primary aim of psychophysics is to understand the relationship between the physics of the world and the psychology of the world, a broader consideration of other findings and issues within naïve physics and phenomenal causality could result in important contributions to psychophysics.

Keynote 2 - Minimal rhythm: How two neighboring time intervals marked by sound onsets are perceived

Yoshitaka Nakajima

Kyushu University/Sound Corporation

Since time connects all pieces of our experience, how time is perceived has attracted the attention of psychophysicists. The concept of time in psychophysics typically appears in relationship between two or more perceptual targets, and it is vital in our everyday life to grasp the durations of neighboring time intervals, to construct and detect repetitions of equal or similar time intervals, and to be aware of difference between successive durations. In this context, my colleagues and I have been collecting and analyzing psychophysical data on the perception of two adjacent inter-onset time intervals marked by onsets of short sounds.

Let t1 and t2 represent two adjacent inter-onset time intervals as perceptual targets, in this order, as well as their physical durations, depending on the context. These time intervals are typically marked by very short sounds of 20 ms or shorter. An inter-onset time interval marked by two very short sounds without any other sound is called an empty time interval. How temporal patterns consisting of two adjacent empty time intervals are perceived is our basic topic.

The whole duration of two adjacent time intervals t1 and t2 can be overestimated but probabilistically (manifesting a bimodal distribution of points of subjective equality) compared with an empty time interval of the same physical duration t1+t2, and the ratio between t1 and t2 tends to be distorted perceptually to be closer to 1:1 than the physical ratio t1:t2 (Nakajima, 1987; Nakajima et al., 1988). If 'the subjective duration of an empty time interval whose physical duration is t' is expressed as $\tau(t)$, a psychophysical relationship $\tau(t) \propto t+\alpha$, where $\alpha \simeq 80$ [ms], gives a rough sketch of these results for empty time intervals between 40 and 1200 ms. We thus reached a hypothesis, the processing time hypothesis (as named by Nakajima et al., 2004), in which the perceptual system needs an additional processing time of α ms to process an empty duration. This hypothesis is connected to a few more well-established phenomena in time perception, e.g., deviation of the Weber's law for sub-half-second empty duration.

Gert ten Hoopen and I noticed that the psychophysical data sometimes indicate local but systematic departure from the above hypothesis, and conducted experiments with our colleagues on the perceptual interaction between two adjacent empty time intervals (Nakajima et al., 2004; ten Hoopen, Miyauchi & Nakajima, 2008). We found that neighboring t1 and t2 sometimes affect one another perceptually. Most noticeably, t2 is systematically underestimated when it is longer than t1. This illusion, time-shrinking, takes place stably if and only if $t1 \leq {\sim}200$ [ms] and ${\sim}0 \leq t2-t1 \leq {\sim}100$ [ms]. Time-shrinking is explained with a modified version of the hypothesis that the additional processing is quickened (and shortened) once t1 and t2 turn out to be nearly equal before the end of the processing, on the assumption that the perceptual system no longer needs very accurate information of t2 in such cases. This explains why the largest underestimation of t2 appears when t2-t1 is around 80 ms, in which case such quickening is assumed to start immediately when the additional processing begins.

Perceptual interaction between t1 and t2 takes place more broadly. Perceptual assimilation between t1 and t2 occurs when ~-50 ≤ t2-t1 ≤ ~150 [ms], and perceptual contrast when ~-200 ≤ t2-t1 ≤ ~-80 [ms] or ~200 ≤ t2-t1 [ms], if t1≤300 [ms] or t2≤300 [ms] (Nakajima et al., 2023). Ten Hoopen et al. (2006) and Miyauchi and Nakajima (2007) noticed the temporal asymmetry of the assimilation range toward the direction of t2-t1 > 0 as above, and reached the idea that this assimilation brings about a perceptual category in which t1 and t2 are perceived with the 1:1 ratio in an asymmetric range of ~-50 ≤ t2-t1 ≤ ~80 [ms], although this range fluctuates between experiments. Time-shrinking occurs in a typical manner on the positive side of this range, and probably causes the asymmetry (Nakajima et al., 2023).

The perceptual interaction between neighboring time intervals does not only depend on the physical timing of sound onsets. Hasuo, Nakajima, and Hirose (2011) conducted experiments on the perception of t1 and t2, lengthening one of the three duration markers from 20 to 60 ms. The total sound energy for each marker was kept constant. If the third marker was lengthened, and if t1+t2 was fixed at 240 ms, time-shrinking was largest when t2-t1 = 40 ms, whereas it was largest when t2-t1 = 80 ms if the third marker was not lengthened. When the third marker, i.e., the second marker of t2, is lengthened, t2 is assumed to be overestimated (Hasuo et al., 2012), and the effective size of t2-t1 should be enlarged. This can somehow explain why the largest illusion took place when t2-t1 was smaller than ~80 ms, the value expected to maximize the illusion otherwise; the longer duration marker is assumed to have increased the effective size of t2-t1 from 40 ms to a value close to 80 ms.

When the first of the three markers was lengthened, t1 was systematically overestimated if it was with t2. Taking up a typical condition, if a time interval of 120 ms, t1, with the first and the second marker of 60 and 20 ms was presented alone, it was perceived just as equal to a time interval of the same physical duration, t2, where both markers were 20 ms. If these t1 and t2 were put together in this order so that they would share one 20-ms marker, however, t1 was overestimated by ~25 ms. It is remarkable that the perceptual effect of the marker to begin t1 is activated more than 100 ms after the judgment target, t1, is presented, i.e., at the end of t2.

Thus, the perception of a minimal rhythmic pattern of two adjacent inter-onset time intervals gives us a rich research area to bridge the gap between time perception studies and rhythm perception studies. If the number of time intervals is increased from two to three, this small step reveals how gestalt principles work in many different ways, reminding us of rhythm in music (Sasaki et al., 2002; see also Desain & Honing, 2003).

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Keynote 3 - Open science and psychophysics: tools to study the mind

Diana Eugenie Kornbrot

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Abstract

Background: psychophysics and quantitative methods

There is a long honourable history of using quantitative data to study the human mind. It comprises numerical measures of performance that vary among individuals and may be affected by experience, training and motivation; and laws relating these measures to each other. Raw measures include: sensation via magnitude estimation and Likert categories; discrimination as proportions of hits and false alarms; and reaction time. Derived theoretical measures include: Steven's power law coefficient; d' and associated response bias criteria; information accrual rate for timed tasks with associated speed accuracy criteria. Much of experimental psychology uses statistics to estimate these descriptive measures and their variance; to test hypotheses about whether predictor effects according to task or population might have occurred by chance (p-value); and the magnitude of any predictor relative to the inherent variability of the target measures (effect size).

The replicability crisis and the Open Science movement

Recently many hallowed experimental results have been called into question as replications fail or are impossible due to unavailability of raw data or details of statistical methods. There is also systematic bias, as non-significant results may not be reported.

Criteria for effective Open Science tools in response to the crisis are considered, including good graphics, effect sizes, and non-linear options. I have created a set of infographic tools embodying Open Science guidelines. These comprise: overview; abstract; introduction (purpose and prior knowledge); sample description (method 1); variables (method 2); analyses including code (method 3); graphic summaries (results 1); descriptive statistics (results 2); inferential statistics (results3); summary and impact; references; acknowledgements; supplementary material; pre-registration. Example use free R based package JAMOVI. G* is useful for a priori power and Lenhard's package for interpreting effect sizes. R, which may require coding, is recommended for more complex theoretical parameter estimation, e.g., for information accrual models.

AI and large language tools are available for: literature reviews, automated summaries of documents and across articles, data extraction and chat functions (Consensus, Scitex, Elicit, SciSpace). AI writing assistants may help with paraphrasing/summarising (Quillbot, Jenni). Map based systems provide cross literature links (Litmaps, Researchrabbit , Connectedpapers). How these evolving tools fare for psychophysics is explored, with some interesting and amusing results.

Summary

Open Science tools are a natural, if arduous, evolution from early psychophysics. In my view they are the way forward to enhance progress in scientific psychology and psychophysics.

Papers and Abstracts for Presentations

Odor-Pitch Interaction; Cross-Modal Integration between Sound and Odor

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Abstract

Odors are difficult to identify and verbalize and people are notoriously poor at identifying odors. Consequently, students of chemo-sensation have increasingly turned to exploring cross-modal correspondences involving odor. Compounding the difficulty is the unavailability of names: Many odors, easily the great majority, are not nameable. Even though they are difficult to identify, some stimuli "go with" others. For example, people are inaccurate at identifying odors presented in inappropriate colors, such as lemon in red or strawberry in yellow (Zellner, 1991; 2013). In this research, we wished to base the connection between odor and pitch. Based on the pioneering research by Belkin (1997) and Crisinel & Spence (2012) with musical pitch, we asked a sample of 40 subjects to match odors to pitch. However, we increased the difficulty level to match voices to odors by using 7 unnamable odors and found that people systematically associated certain sounds at a definite pitch with certain odors.

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Towards Multimodal Steven's Power Law using Neural Coding

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Abstract

Our sensory systems are complex networks that interpret and translate the raw data from our environment into meaningful experiences. The psychophysical laws simplified the complex sensory experience by assuming only one sensory modality at a time. The Stevens' power law links the magnitude of one physical stimulus presented at a time to its perceived internal intensity via a psychophysical power function. The widely known Steven's power law is restricted to unimodal sensory experiences. Extension of the power law to multimodal sensory experience could be useful in many practical applications. However, the challenge of conducting experiments for measuring multi-modal power law is that combination of sensory stimuli would be exhaustive and practically impossible. Instead, we propose the use of neural coding to determine the multi-modal power law. The rationality of this approach is based on the work of Mountcastle and his colleagues that inferred that subjective intensity must be related linearly to the neural coding measure on which it is based. We examined this approach in the following experiments and simulations. We investigated the integration of mechanical and electrical stimuli to understand tactile perception through both experimental and computational approaches. By applying sub-threshold vibrotactile stimuli alongside electrotactile stimuli, we observed significant reductions in Electrotactile Perception Thresholds (EPT), highlighting the synergistic effects of multimodal stimulation. Computational models of Pacinian Corpuscles (PCs) were developed to simulate responses to these stimuli, demonstrating how sub-threshold stimuli enhance PC excitability. The spike-rate plateaus observed in the models were linked to Just Noticeable Differences (JNDs), establishing a connection between neurophysiological responses and psychophysical thresholds. These findings provide a foundation for extending Steven's power law to multimodal sensory experiences, offering a comprehensive understanding of sensory integration. Our findings have practical implications for designing more sensitive and effective tactile feedback systems, with potential applications in prosthetics and haptic interfaces. Future research should explore additional stimulus modalities and long-term sensory adaptation.

Introduction

Understanding human perception through both experimental and computational methods is a key objective in psychophysics. Psychophysical experiments provide empirical data on how stimuli are perceived, while computational models offer insights into the underlying neural mechanisms. This paper combines findings from several studies to explore tactile perception, focusing on the interplay between experimental results and computational simulations.

Research in tactile sensation has explored various parameter spaces in terms of perception and neurophysiology. We focus on both vibrotactile and electrotactile sensations. In electrotactile perception, we explored spatial summation and frequency response of stimulation. For instance, we demonstrated that the spatial arrangement and intensity of stimuli significantly affect tactile perception [1]. Furthermore, our experimental investigations on vibrotactile thresholds and sensory adaptation have provided us with an idea of how different frequencies and amplitudes of stimuli are processed by the tactile sensory system. Through computational models, we simulated physiological responses of mechanoreceptors, specifically, Pacinian corpuscles, responsible for mechanotransduction of vibratory signals applied over the skin. Our models help understand how electrical [5] and mechanical stimuli [6] are transducted into neural signals.

The integration of these experimental and computational approaches allows for a more holistic understanding of tactile perception. This paper aims to synthesize the insights gained from our studies and computational models, providing a comprehensive perspective on the mechanisms of tactile perception and suggesting avenues for future research.

Methodology and Results

This research employed a combination of psychophysical experiments and computational modeling to investigate the integration of mechanical and electrical stimuli on tactile perception. We conducted a series of experiments to measure perception thresholds and developed detailed computational models to simulate the physiological responses of Pacinian Corpuscles (PCs) to these stimuli.

Experiment-I: ElecroTactile with VibroTactile (ETVT)

In the first experiment, we utilized a 90% subthreshold vibrotactile stimulus as a background to measure the threshold for electrotactile stimulation. The experimental setup (Figure 2(a)) included two electrodes (anode and cathode) for electrical stimulation and a linear resonance actuator (LRA) positioned between the electrodes for vibrotactile stimulation [1]. Seventeen participants were tested individually for electrotactile and vibrotactile thresholds using the staircase method of classical psychophysics. After calculating the 90% subthreshold for the vibrotactile stimulus, we fixed its amplitude as background. The average electrotactile perception threshold (EPT) was determined from 10 trials across six frequencies ranging from 20 Hz to 640 Hz, selected on a logarithmic scale. Results shown in Figure 2(b), indicated a 3-5% reduction in EPT with the 90% subthreshold vibrotactile background.

Experiment-II: Spatial Summation of ElecroTactile Displays

In the second experiment, we examined the simultaneous excitation of the skin with two different subthreshold electrical stimuli. Using a common cathode and two separate anodes, we conducted electrotactile stimulations with the same basic setup as the first experiment, exploring Electrotactile Perception Thresholds (EPTs) across frequencies from 20 Hz to 1280 Hz [2]. The experiment had two stages. In the first stage, both stimuli were of the same frequency. We measured the threshold for the first stimulus, reduced it to various subthreshold levels (50% to 90%) as background, and then measured the EPT for the second stimulus. Figure 1(c) shows EPT variations from 20 Hz to 1280 Hz. Vth-I and Vth-II represent the independent EPTs of the first and second stimuli, respectively, while Vth-IIa to Vth-IIe show the EPT variations for the second stimulus with the first stimulus maintained at 90%, 80%, 70%, 60%, and 50% subthreshold, respectively. EPT reductions ranged from 5% at lower frequencies to 60% at higher frequencies.

In the second stage, the first stimulus was fixed at 30 Hz, and the EPT for the second stimulus was measured. Figure 1(d) shows the frequency response of EPT, with Vth-II representing the second stimulus alone and Vth-IIb with 20% subthreshold background stimulation at 30 Hz. EPT reductions ranged from 19% to 57%. This experiment demonstrated the spatial summation of two subthreshold electrotactile stimuli, reducing their thresholds and contributing to safer tactile feedback systems.

Experiment-III: Electrovibration with ElecroTactile (EVET)

Electrovibration uses an alternating current (AC) through the conductive layer of a capacitive touch screen to adjust the friction experienced by the user's finger. By modifying the frequency, amplitude, and waveform of the AC signal, different textures can be simulated, leveraging electrostatic friction principles to create an attractive force between the user's finger (cathode) and the screen (anode) [3]. A major challenge with electrovibration is the high voltage requirement (up to 300 Volts). To address this, we used subthreshold electrotactile stimulation (SES) as a background to reduce the threshold for electrovibration. In our experiments, subthreshold electrotactile feedback was applied to the scrolling finger (right hand index finger) at 90% and 80% levels. This reduced the thresholds for electrovibration by 12.46% and 6.75%, respectively. Figure 2(a) illustrates the frequency response of electrovibration thresholds (EV) with and without SES. The EV threshold was lower with 90% SES compared to 80% SES.

We also evaluated the perception of combined stimuli by asking users to rate their perception on a Likert scale from 1 (pure electrotactile) to 5 (pure electrovibration). The perception shifted towards pure electrovibration with 80% SES and was balanced between 1 and 5 with 90% SES, as shown in Figure 2(b).

Experiment-IV: Electrovibration with VibroTactile (EVVT)

We conducted an additional experiment using vibrotactile actuators as subthreshold stimuli to further reduce the threshold for electrovibration. Four LRAs were placed at the corners of the touch screen, controlled by a DRV2605 LRA driver and an ARDUINO UNO to manage waveforms and amplitudes. After measuring the LRA amplitudes, we applied 80% and 90% subthreshold stimulation in the background and measured the thresholds for electrovibration [4]. Figure 2(c) shows the frequency response of electrovibration thresholds (EV) under three conditions: EV alone, EV with 90% subthreshold vibrotactile stimulus (EV-I), and EV with 80% subthreshold vibrotactile stimulus (EV-II). We also evaluated the combined perception on a Likert scale from 1 (pure vibrotactile) to 5 (pure electrovibration). Figure 2(d) illustrates this experiment's representation. The combined perception shifted more towards pure electrovibration compared to the EVET experiment.

Computational Modeling of Pacinian Corpuscles for Hybrid Stimulation

Computational models of Pacinian Corpuscles (PCs) provide a detailed understanding of how these mechanoreceptors respond to various stimuli. These models simulate the biomechanical and neurophysiological processes that occur when PCs are stimulated, enabling researchers to predict responses to different types of stimuli, including mechanical and electrical. The electrical stimulation computational model [5] focuses on how PCs respond to electrical stimuli applied to the skin. This model includes detailed components such as the electrode-skin interface, neurite, and the first Ranvier node. The electrical stimulus, typically a current pulse, induces an action potential in the PC's axon. The model accounts for various parameters, including the amplitude and frequency of the stimulus, to simulate the resulting spike-rate characteristics and threshold levels.

The hybrid stimulation computational model extends the analysis to simultaneous mechanical and electrical stimuli. This model integrates the biomechanical properties of the skin and lamellae with the electrical properties of the electrode-skin interface. The hybrid model allows for the study of how combined stimuli affect the excitability of PCs. The model simulates the spike response of PCs under combined mechanical and electrical stimuli, showing how sub-threshold stimuli of one type can influence the response to supra-threshold stimuli of another type. The model demonstrates a monotonic decrease in the stimulus threshold as the amplitude of the sub-threshold stimulus increases, indicating enhanced excitability due to hybrid stimulation [7]. Figure 3 sows the computational model and the results.

Discussion

Our research explored tactile perception through a combination of experimental and computational approaches. Our findings provide valuable insights into how different types of stimuli, specifically mechanical and electrical, interact to influence sensory perception. By employing a series of experiments and developing detailed computational models, we have advanced the understanding of neurophysiological and psychophysical thresholds in the context of multimodal stimulation.

The experiments involving the simultaneous application of mechanical and electrical stimuli revealed significant interactions between these modalities. The results demonstrated that sub-threshold vibrotactile stimuli can reduce the thresholds for electrotactile perception, as evidenced by the consistent reduction in Electrotactile Perception Thresholds (EPT) when a background vibrotactile stimulus was present. This interaction highlights the potential for multimodal stimulation to enhance the sensitivity and accuracy of tactile feedback systems, which could be particularly beneficial for applications in prosthetics and haptic interfaces.

Computational models are crucial for developing a deeper understanding of sensory integration and perception. By using these models, researchers can explore the multimodal extensions of Steven's power law, starting with the integration of electrical and mechanical stimuli. This approach provides a framework for studying how different sensory modalities interact and influence the perception of intensity, with potential applications in fields such as prosthetics, sensory augmentation, and virtual reality.

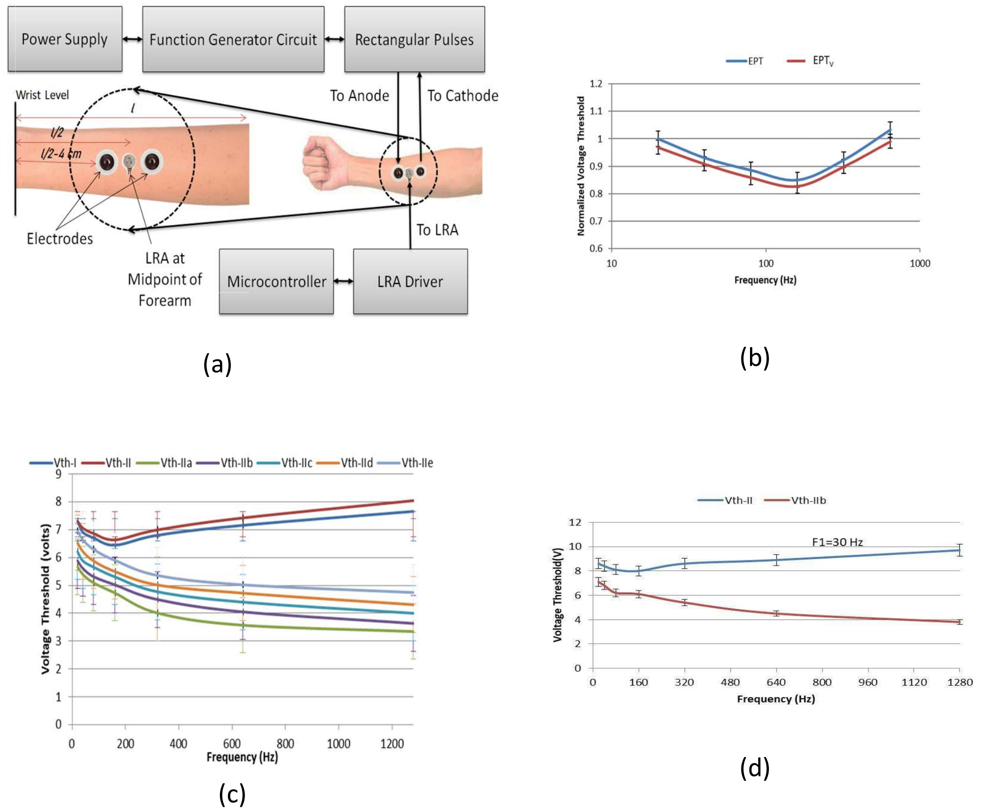

Figure 1. (a) Set-up for ETVT, (b) Experimental results from ETVT, (c) Results from Spatial summation experiment when both stimuli had same frequencies, and (d) Results from Spatial summation experiment when both stimuli had different frequencies

Implications for Multimodal Steven's Power Law

The study's results offer a foundation for extending Steven's power law to multimodal sensory experiences. By establishing the relationship between spike-rate characteristics and JNDs, we can formulate a multimodal power law that incorporates both mechanical and electrical stimuli. This extended power law can provide a more comprehensive understanding of sensory perception, accommodating the complexities of real-world stimuli that are often multimodal.

The insights gained from this study have several practical implications. In the design of tactile displays and haptic feedback systems, understanding the interaction between different types of stimuli can lead to more responsive and effective devices. For instance, incorporating sub-threshold stimuli to enhance the perception of primary stimuli can improve the sensitivity and user experience of haptic interfaces. Additionally, the findings could inform the development of advanced prosthetic devices that provide more natural and intuitive feedback to users.

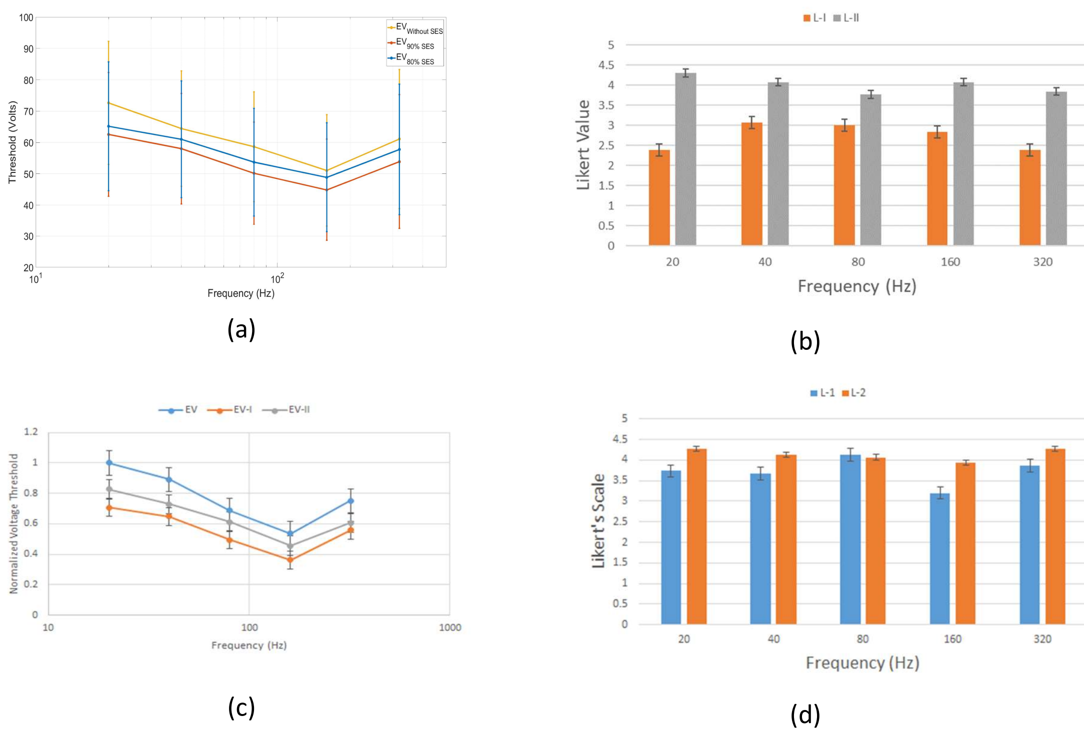

Figure 2. Experimental results from the subthreshold experiments for electrovibration (a) Variation of thresholds for electrovibration with and without SES over frequency for EVET experiment (b) Likert scale representation for EVET, (c) Variation of thresholds for electrovibration with and without SES over frequency for EVVT experiment, and (d) Likert scale representation for EVVT

Future Research Directions

Future research should aim to expand on the findings of this study by exploring other combinations of stimuli and their effects on tactile perception. Investigating additional modalities, such as thermal or chemical stimuli, could further enhance our understanding of multimodal sensory integration. Moreover, longitudinal studies examining how sensory perception adapts to prolonged multimodal stimulation would provide insights into the long-term effectiveness of these approaches. In conclusion, this study has advanced the field of tactile perception by integrating experimental and computational methods to explore the interactions between mechanical and electrical stimuli. The findings not only enhance our understanding of neurophysiological and psychophysical thresholds but also pave the way for developing more sophisticated models and applications in tactile feedback systems.

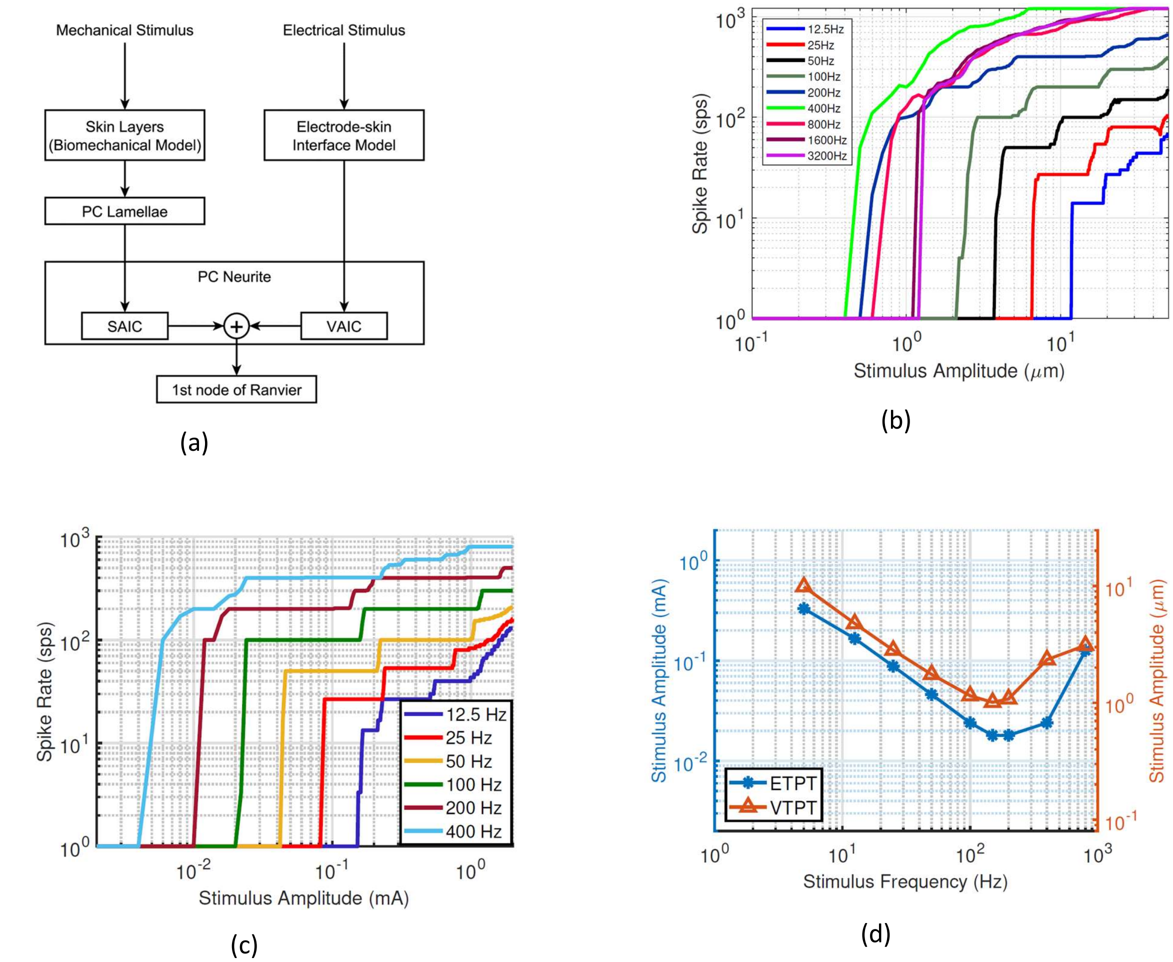

Figure 3: Simulation results from computational models of Pacinian corpuscles. (a) block diagram for hybrid stimulation (simultaneous mechanical and electrical stimulation), Spike rate characteristics for (b) mechanical stimulation and (c) electrical stimulation, and (d) electro-tactile and vibrotactile perception threshold (ETPT and VTPT) curves.

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Pupillary Light Response in Vertical and Horizontal Fields of View

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Abstract

The pupillary light response (PLR) can reflect covert shifts of attention. Mathôt et al. (2013) developed a split-screen paradigm in which the right and left parts of the screen are either white or black, respectively. When presented with a spatial cue, the pupil is expected to respond to the luminance in the corresponding spatial direction. For example, if a cue directs attention to the right side of the screen, which is black, pupil dilation will occur. Salvaggio et al. (2022) presented this PLR affected by an auditory spatial cue, even in the absence of eye movements from the center (which was gray), indicating a covert attentional shift. This basically means it is naïve to assume that fixating our eyes on the center of the screen means that our attention is acting the same.

Here, we report two analyses based on the horizontal split-screen (derived from Slalvaggio's raw data) and a vertical split-screen in the current experiment. We reanalyzed Salvaggio's data to determine whether a covert attentional shift occurred before the onset of the experimental manipulation, driven by the screen luminance manipulation alone. Our analysis revealed a covert attentional shift to the right that influenced pupil size, matching the luminance on the right side of the screen, independently of the experimental manipulation. These results led us to explore covert attentional shifts using a vertical split-screen. In our experiment, participants viewed a vertical split-screen in both variations (black on top, white on top) and were instructed to fixate on the center of the screen and press a key upon hearing a sound. Our findings demonstrated an upward covert shift of attention, as pupil size matched the luminance of the upper part of the screen, regardless of whether it was black or white. Once again, the PLR appeared before the auditory spatial cue onset while the participants were fixated on the gray center of the screen.

This study highlights the ability of pupil size to indicate covert attentional shifts in both vertical and horizontal screens, even when participants are instructed to look only at the center of the screen. Notably, our use of the split-screen paradigm revealed that attention is biased upwards and to the right in the absence of attentive manipulation. The findings could be explained by spatial search patterns, suggesting a covert attentional preference for upward and rightward directions. Following previous findings (Shaki, 2013; Tversky et al., 1991), further research is required to investigate whether cultural differences, such as reading directions, could influence the outcomes.

Anthropogenic and Natural Soundscapes: How Environment Colors our Subjective Experience of time

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Abstract

Exposure to different environments can profoundly impact physical and mental health as well as cognitive abilities such as attention and time perception. While numerous studies have explored how urban and natural settings influence temporal processing, certain questions remain unanswered. Specifically, the effect of *Anthropogenic* and *Natural* soundscapes on time perception and the underlying mechanisms, such as the pacemaker or attentional gate, have not been fully understood. To investigate these questions, we conducted two experiments using a temporal bisection task. In Experiment 1, Anthropogenic and Natural soundscapes were varied based on arousal and valence levels. In Experiment 2, we examined whether differential temporal processing resulted solely from differences in arousal or valence levels, or if the categories of soundscapes (Anthropogenic and Natural) also influence temporal judgment. For Experiment 2, arousal and valence were matched for both categories of soundscapes. We presented these soundscapes to 40 volunteers in Experiment 1 and 42 volunteers in Experiment 2, randomly intermixing the sounds for durations ranging from 400ms to 1600ms. Each participant performed 140 trials for Experiment 1 and 224 trials for Experiment 2. The results consistently indicated no significant difference in the *Difference Limen* (DL), while the *Point of Subjective Equality* (PSE) for both categories of soundscapes differed significantly. This suggests that Anthropogenic soundscapes were consistently overestimated relative to Natural soundscapes. Our findings suggest that the attentional gate mechanism contributes to differential temporal processing. It may be possible that participants directed more attention toward the temporal properties of Anthropogenic soundscapes, leading to an expansion of perceived time for such sounds. Additionally, our results reveal that differential temporal processing is not solely attributed to variations in arousal or valence levels; rather, the content and category of soundscapes play a crucial role in temporal judgment. Overall, this study highlights how different settings modulate our temporal estimates.

Preceding Temporal Context Enhances Temporal Resolution

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Abstract

Temporal resolution, the ability to distinguish the order of briefly presented stimuli, is traditionally considered a fixed feature with a typical range of 30-50ms. Events presented within this timescale are generally perceived as simultaneous. This understanding of temporal resolution stems from the Simultaneity Judgment (SJ) paradigm, where two isolated events are presented with varying Stimulus Onset Asynchronies (SOAs). However, in nature, events of interest are preceded by other events and how they influence subsequent perception of simultaneity and temporal resolution is not clear. In this study, we investigated how a preceding event (Anchor) affects the temporal resolution of subsequent target events (C1 and C2) using a three-event SJ paradigm. We asked participants to perform SJ tasks for C1 and C2 either in isolation (phase 1) or after another event (A) (phase 2). We manipulated SOA between C1 and C2 and A and C1, in the range of 10-80ms. The events were either duration-matched (experiment 1) or offset-matched (experiment 2). The results show an increase in resolution when C1-C2 is presented after A (with maximum resolution at 80ms). This is a novel finding that cannot be explained by using standard models of SJ. Next, we investigated how the temporal gap between A and C1 influences this phenomenon (experiment 3). We manipulated the SOA between A and C1 in the range 10 to 450ms. The results showed that the improvement in temporal resolution persisted up to 150ms but diminished beyond that. Together, the results demonstrate a phenomenon where a temporal resolution for an event shows an increase when preceded by another event in the range of 40ms-150ms. These results demonstrate that temporal resolution is influenced not only by the SOA between events but also, by the preceding temporal context.

Neural Correlates of Time of Day Effects on Inhibitory Control

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Inhibitory control performance has been shown to vary across the time of the day (TOD), with these daily variations depending on the individual's chronotype (morning-/evening-type). The synchrony effect hereby predicts better performance at optimal as compared to non-optimal TOD. While some studies observe the synchrony effect, in other studies the absence of the synchrony effect was explained by increased compensatory brain activity. Additionally, variability in findings across studies could be explained by various tasks being used interchangeably as measures of inhibitory control, although the multifaceted construct of inhibitory control includes similar yet distinct subtypes which could be differentially sensitive to TOD. Hence, we investigated the effect of TOD separately for the three inhibitory control subtypes: maintaining goal in face of distraction caused by (1) self-generated information, (2) perceived environment or (3) habits. To this end, we recorded the EEG activity of young male adults with the evening-chronotype while performing one experimental task associated with each inhibitory control subtype (N-Back, Flanker, and Navon, respectively) both in the morning (non-optimal session) and the evening (optimal session). For the N-Back and Navon task, we found synchrony effects in the reaction times as well as TOD effects in the N2 and P3 ERP components which were affected by the order of the sessions (optimal vs. non-optimal session first). For the Flanker task, TOD effects in ERP components were found even in the absence of behavioral differences highlighting the sensitivity of ERPs to detect TOD effects. Hence, between-task differences confirmed the notion of differential TOD effects on the distinct inhibitory control subtypes. Findings are relevant for the regular educational and working life of evening-chronotypes as they are frequently expected to perform at non-optimal times of their day.

The Endless Global Precedence Effect: Behavioral Dynamics Between Global Precedence and the Fast-Same Effect

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Abstract

The fast-same effect (FSE) occurs when object pairs are compared for sameness or difference: "same" responses are faster and/or more accurate than "different" responses. The FSE is typically explained by fast holistic processing of identity, whereas analytic processing is reserved for differences amongst the pairs. We studied the role of holistic processing in the same-different task, using stimuli whose holistic and analytic processing properties are well-known, viz. the Navon compound figures. These figures consist of two hierarchical levels: a global and a local one. Processing of these figures commonly exhibits a global precedence effect (GPE), resulting from early holistic processing of the global level, followed by analytic processing of the local level if required by the task. We predicted that an FSE would occur in the same-different judgments of Navon figure pairs, regarding the global level but not the local one. Our results are based on secondary analyses of data previously used by Ventura et al., (2021). We observed an FSE for the global level judgments as predicted. In addition, there was also an unexpected fast-same effect for the local level but only when figure pairs were also "same" at the global level. This effect can be understood

as resulting from the GPE. We conclude that these results confirm the notion that the fast-same effect results from holistic processing.

Introduction

Human perception often involves hierarchical stimuli, in which we distinguish between local and global levels (Kimchi, 1992; Palmer, 1977; Poirel et al., 2008). Typically, processing starts on the global level before the local level (Navon, 1977). *Global* is often used as a synonym to holistic processing, to describe the initial stages of object identification, discrimination, or classification (Kimchi, 1992). We refer to *holistic processing* for perceiving an object as a unitary, integral whole rather than a collection of components (see Kimchi, 1992). *Local* is often identified with *analytic processing.* We will use this term to describe breaking down a coherent integral percept into independent parts, in order to engage with them in piecemeal fashion (Kimchi, 1992; Navon, 1977). Compound, hierarchical figures (Navon figures, Fig. 1) are characterized by their overall shape, typically observed at the global level. The global shape is constituted as a configuration of local elements at a lower level of the hierarchy, e.g. a number of local circles arranged in the form of a square. Navon figures are used in a variety of tasks, usually involving a selective response to the local or global level. When local and global level are incongruent (e.g. circle of squares), interference from the irrelevant level could be expected on the task-relevant one, compared to when the two are congruent (e.g. circle of circles). In these tasks, typically a *global precedence effect* (GPE) is observed (Poirel, 2006), enveloping two component-effects: a *global advantage* (GA) and a *global interference* (GIE). The former denotes faster reaction times (RT) and/or higher accuracy in responses to the global than to the local level, while the latter involves an asymmetric congruence effect: for local components there is an effect of congruence with the overall shape, whereas this effect is absent for the global level.

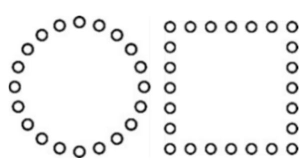

Figure 1. Compound Stimuli (Navon figures). Left: a congruent Navon figure (a circle of circles); Right: an incongruent Navon figure (square of circles).

Whereas Navon figures have been used in a variety of tasks, they have rarely been applied in a *same-different* task. In this task, pairs of Navon figures can be judged for sameness or difference at either the local or global level or a combination of both. When both levels matter for sameness, this amounts to a physical sameness task; when only one level matters, this amounts to a categorical sameness task (e.g. Gao et al., 2011; Hübner, 1998). In the *same-different* task, a *fast-same* effect (Nickerson, 1965; 1967) occurs when a pair is identical at both the relevant and irrelevant feature level compared to identity at the relevant level only. This suggests that, despite the instruction, the irrelevant level cannot be ignored. On one interpretation of the *fast-same* effect, this is because *same* responses are made holistically (Cleaves, 1977). In Navon figures, global precedence is understood as a matter of holistic processing. This enables us to investigate whether the *fast-same* effect is due to holistic processing. We expect a *fast-same* effect for the global, but not necessarily for the local level. We reanalysed data from Ventura et al., (2021), Exp. 1, who used the task as preparation for a subsequent experiment and considered only for the factors Instruction (local/global) and Response Type (same/different). We additionally distinguished what response the figure pair calls for at the level that is irrelevant according to Instruction, i.e., Matching (match/non-match). For example, if Instruction is global and a figure pair calls for *different*, we have a non-match condition when the irrelevant local level calls for the *same* response (Fig. 2).

Methods

Participants

A total of 24 participants aged between 20 and 31 years (*M*=25.75, *SD*=3.18) took part in the study (12 male, 12 female). The experiment was approved by the Ethics Committee of the Department of Psychology of the University of Lisbon. For more details on participants, stimuli, design and procedure see Ventura, et al. (2019, p. 2192-2194).

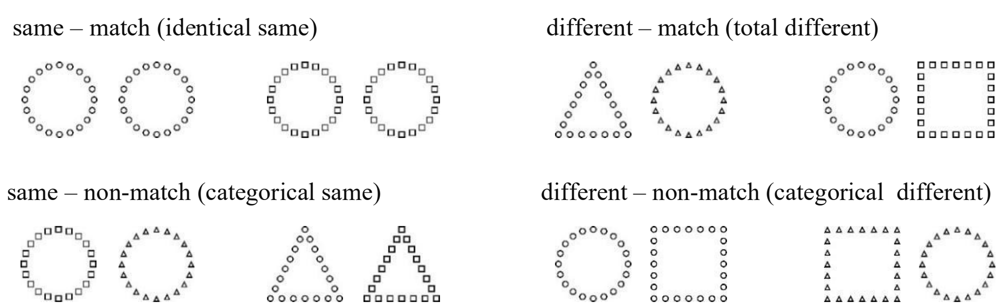

Figure 2. Depiction of the conditions for Response type and Matching on global Instruction level. *Top left image.* Figure pair calls for the 'same' response on the task-relevant instruction level (global), and for the 'same' response at the task-irrelevant level (local), leading to a match condition. As both figures in a pair are identical, we distinguish this condition as *identical same*. *Top right image.* Figure pair calls for the 'different' response on the task-relevant instruction level (global), and for the 'different' response at the task-irrelevant level (local), leading to a match condition. As figure pair calls for 'different' response on relevant and task-irrelevant instruction level we distinguish this condition as *total different*. *Bottom left image.* Figure pair calls for the 'same' response on the task-relevant instruction level (global), but for the

'different' response at the task-irrelevant level (local), leading to a non-match condition. As both figures in a pair are only same in regard to a category relevant for the task, we distinguish this condition as *categorical same*. *Bottom left image.* Figure pair calls for the 'different' response on the task-relevant instruction level (global), but for the 'same' response at the task-irrelevant level (local), leading to a non-match condition. As both figures in a pair are only different in regard to a category relevant for the task, we distinguish this condition as *categorical different*.

Stimuli and apparatus

Similar to Fig.1, four basic global figures (Circles, Squares, Triangles, and Rhombi) with a visual angle (VA) of 4.96° height/width were created out of local elements of 0.42° of VA of the same shapes, yielding 16 compound figures (Ventura et al., 2019, p. 2193). The visual angle sizes of the global shapes and local components, as well as their ratio were based on the literature (Amirkhiabani & Lovegrove, 1996; Bouvet et al., 2011; Gao et al., 2011; Harrison & Stiles, 2009; Hübner, 1998; Kimchi, 1992; Kimchi, 2003; Kinchla & Wolfe, 1979; Matthews & Martin, 2009, 2016; Schmitt, 2026;). An optimal size for obtaining the GPE of 5° VA for the global shape and 10% of that for the local shape, but no less than 0.3°VA, was used. A 20-inches CRT monitor (Hitachi CM813ET Plus) was used.

Design and procedure

We applied a categorical *same-different* task with two versions of the instruction (global/local) with an identical sequence of events. The two instructions (global/local) and response keys (q-'same', p-'different'; q-'different', p-'same') were combined in a total of four blocks, whose order was fully counterbalanced within and between participants. Each trial started with a 500 ms fixation cross followed by a Navon figure pair for 2000 ms or until response. Feedback was given 500 ms after the response ("Correct!", "Incorrect," or "Time-out,").

Results and Discussion

Overall accuracy was above 93% and further analyses of RT was computed after removal of incorrect responses, with a cutoff time of less than 150 ms and more than the Mean+2*SD per level per participant. We conducted repeated measures ANOVAs on RT and error rates (ERR) for Instruction level (global or local), Response type (pairs calling for 'same' or 'different' responses) and Matching (match or non-match at the irrelevant level).

For RT, main effects were observed for all three factors: Instruction, Response type and Matching ($p < .001$, for all). The interaction of Instruction and Response type was not observed ($p = .739$), confirming that global responses are faster overall than local ones, and 'same' are overall faster than 'different' responses (Figure 5).

Interactions of Instruction and Matching, Response type, and Matching, as well as of all three factors was obtained (all $p < .001$; Figure 3). Post hoc analyses showed that 'same' responses on the global level Instruction were faster than 'different' responses, irrespective of Matching. We conclude that the fast-same effect on the global level occurs regardless of the identity on the local level. On the other hand, on the local level, it depends on matching whether 'same' responses are faster than 'different' responses. Only in matching conditions, local level 'same' responses are faster than 'different' responses. The fast-same effect at global level was as predicted. Its unexpected occurrence even if the local level features differ between the figures, implies that the local level is ignored in holistically processing of the compound stimuli. Because of the global advantage, fast-same responses at global level can be made before analyzing the local level. The fast-same effect unexpectedly occurred also at the local level, albeit modulated by Matching. 'Same'- match conditions (i.e. identical same, see Figure 2) are faster than 'same' non-match conditions (i.e. categorical same). There are two likely explanations for this - either the global level 'sameness' facilitates local level 'same' responses or, alternatively, congruency between the local and global levels of both figures facilitates the fast-same effect for the local level. This explanation is in accordance with the GPE for Navon stimuli.

For ERR, main effects were observed for all three factors: Instruction, Response type, and Matching (p = .009, p = .010, p = .001, respectively). No interaction of Instruction and Response type was observed (p = .065), while ones of Instruction type and Matching, as well as Response type and Matching were found (p = .009, p = .007, respectively). Unlike in RT, no interaction of all three factors was obtained (p = .995) (Figure 4). Post hoc analyses revealed that global Instruction produced fewer errors than the local one only in matching conditions, regardless of Response type, unlike in RT analyses, where global Instruction had a significant advantage in all conditions (Figure 5). Global to local interference strongly increases the ERR in local – non-matching conditions equally for 'same' and 'different'. This supports our previously discussed understanding of the unexpected fast-same effect at local level as an effect of congruency between the local and global levels of both figures. Also unlike for RT, same – non-match, different – match, and different – non-match showed no ERR differences at the global Instruction. Post-hoc analyses for the local Instruction were consistent to the ones in RT analyses. We may conclude that the data are in accordance with holistic processing for fast-same trials. In addition, we observed that that this extends to categorical sameness conditions for the global instruction task. For this task, the local level is ignored, in accordance with the global advantage. Finally, we found a fast-sameness effect for the local level task, however, only in matching trials, suggesting facilitation of either global level sameness or congruency. Note, however, that these results are based on a reanalysis of an existing dataset. The research question did not require an analysis of Matching conditions, leading to imbalanced stimulus frequencies. It is currently unknown whether these imbalances could explain some of the effects. A replication of this study with balanced stimuli is currently being conducted.

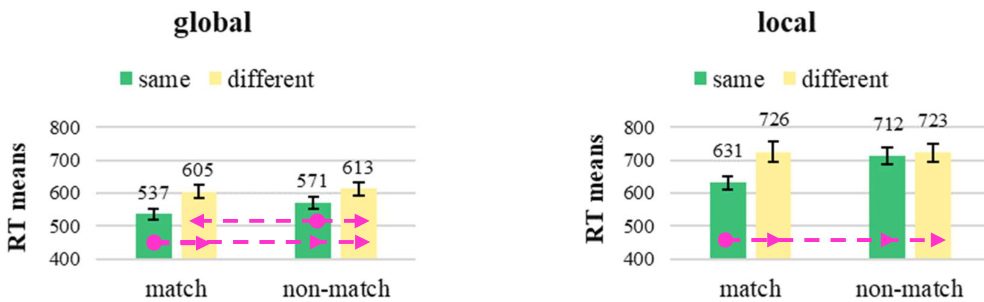

Figure 3. RT means Response type and Matching conditions per Instruction level. Note. Magenta arrows indicate significant differences between conditions. Conditions marked with dots differ from all the ones marked with an arrow. The arrows point to direction from faster to slower conditions. Bars represent the +/-1 standard error of the mean across all figures.

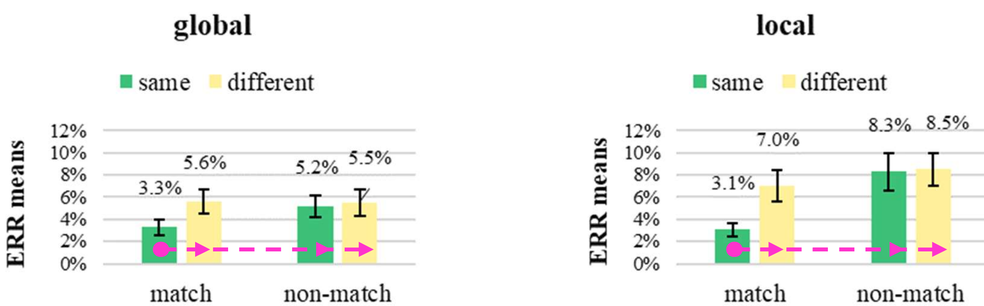

Figure 4. ERR means Response type and Matching conditions per Instruction level.

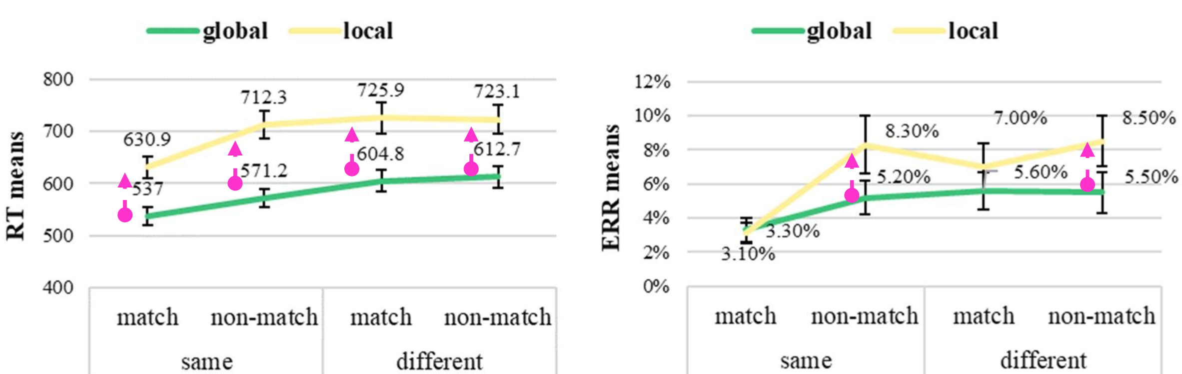

Figure 5. Response type and Matching conditions differences across Instruction levels.

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A Double Dissociation between Neural Mechanisms of Reward-Driven Sensory and Decisional Selection

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Abstract

Reward expectation robustly guides behaviour and engages both attentional and decisional processes. However, whether these processes are mediated by overlapping or distinct mechanisms remains unknown. Previous studies have often conflated the effect of reward expectation on prioritized sensory information processing (perceptual sensitivity) and decision-making (choice criterion) because locations selected for improved sensory processing were also the targets of subsequent motoric decisions. In our study, we demonstrate that distinct forms of reward-guided modulations, i.e., across spatial locations ("space-specific") and across choices ("choice-specific"), control spatial attention and decision-making in a dissociable manner in the human cortex. Sensitivity and criterion were modulated independently when expected rewards varied in a space-specific or choice-specific manner, respectively. First, only sensitivity, not criterion, modulations reflect a globally conserved attentional resource. Second, established neural and physiological signatures of attention, including amplitude gain of posterior event-related potentials (N2pc, P300), stronger post-stimulus alpha-band power lateralization, and increased microsaccadic biases, were elicited only by space-specific reward modulation. By contrast, choice-specific reward modulation selectively engaged neural signatures of decision-making, like the pre-stimulus alpha-band power changes. Third, the forementioned established neural markers of attention predicted sensitivity modulation by space-specific reward expectation but not criterion modulation by choice-specific reward expectation, indicating distinct underlying mechanisms between space- and choice-specific reward-guided attention. Thus, our findings reveal fundamentally dissociable mechanisms that mediate the effect of reward expectations on sensory and decisional selection, with critical implications for understanding the neural basis of reward, attention, and choice, as well as how they are linked in the human brain.

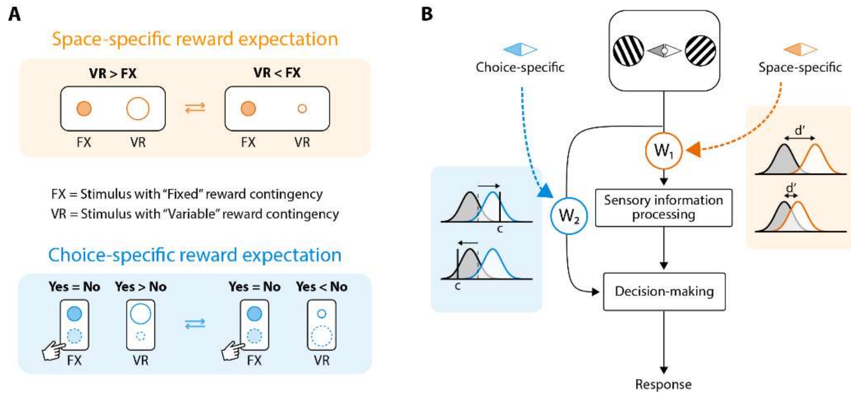

Figure 1. Schematic of dissociated effects of space-specific and choice-specific reward expectation on attentional and decisional processes. A. Schematic of the space-specific (*top*) and choice-specific (*bottom*) reward expectation sessions. Reward contingency at a location either remained fixed (FX) or varied (VR) across trials. **B.** Modulating reward expectation across space (FX vs VR) versus across choice ('Yes' vs 'No') produces selective effects on attention and decision-making processes. Gaussian distributions in one-dimensional signal detection theory models (SDT) show modulations of sensitivity (d') or criterion (c) in the two distinct reward-driven sessions. Filled grey and white: noise and signal distributions, respectively. w1: prioritized weighing for the sensory processing of stimuli; w2: prioritized weighing of the choice alternatives.

Immediate Spatial Cuing of the Initial Display Does Not Influence Change Detection Performance in Natural Scenes

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Abstract

Change detection (CD) is often poor in people due to the fleeting nature of visual representations or limited capacity visual short-term memory. Some have argued for a larger capacity and better change detection capability using post-cues. Previously, we investigated this issue by manipulating cuing-time (pre, ISI, post) and attentional breadth (small cue, large cue) in a CD paradigm with natural scenes as stimuli. The results showed that CD capacity is limited. Cuing helped change detection performance only for pre-cues and not for ISI or post-cues. Also, performance was better with the small pre-cue compared to the large pre-cue. However, one limitation of this study was that the ISI between the two displays was 2000ms and the ISI-cue was presented only at 900ms. It is possible that performance would have been better if the ISI-cue was provided much earlier immediately after the offset of initial display when the visual representations are still in the fragile-visual short-term memory with less time for decay of visual information. Therefore, in the current study, we presented spatial cues at three different time-points (at 300ms, 600ms, and 900ms) during the ISI-condition in addition to manipulating attentional breadth with the size of the cued region. Thirty-two participants participated in the experiment. Signal detection theoretic measures (d' and criterion) were calculated for individual change detection data. Repeated measures ANOVA was performed with cue-timing (300ms, 600ms, and 900ms) and cue-size (narrow, wide) as factors. Results showed no effect of cuing-time or size on change detection performance. At all the three time-points, attentional breadth did not influence change detection. The results indicate that either there is very fast information decay (within 300ms) or that there is very little information stored from the first display in visual short-term memory or overwriting of visual representations by the second display making change detection harder.

Role of the Right Parietal Cortex in Mediating Subcomponents of the Attentional Blink

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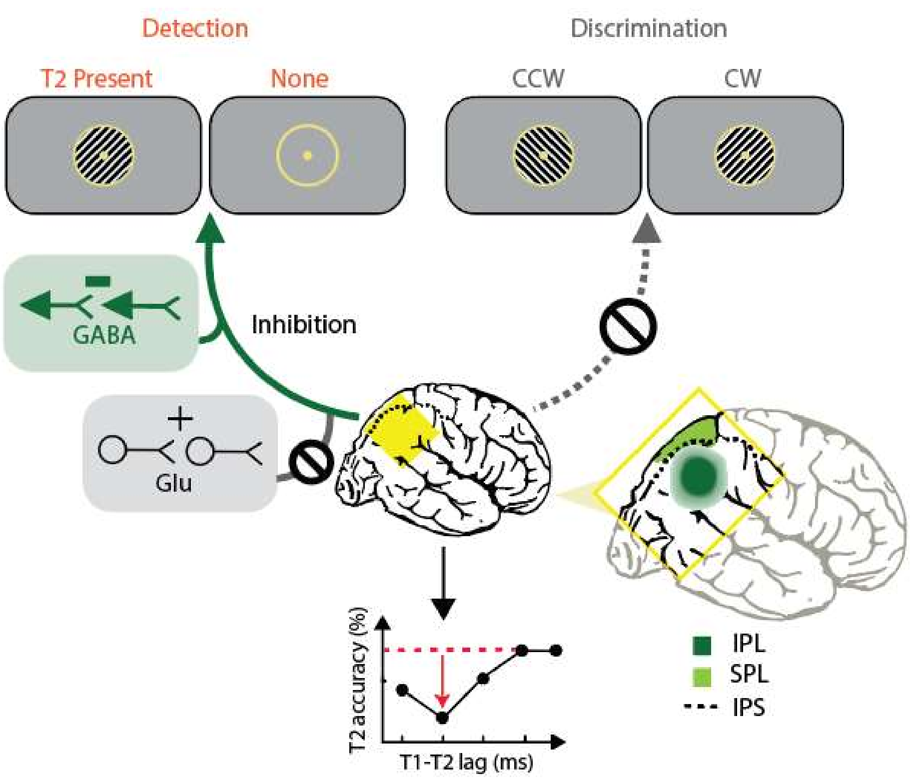
Abstract

The attentional blink reflects a deficit in processing the second of two targets that occur closely in time. Recent research suggests dissociable neural mechanisms mediate distinct subcomponents – detection and discrimination deficits – associated with the attentional blink. The right posterior parietal cortex (rPPC) has been extensively studied for its involvement in temporal attention, but its precise role in mediating each component of the attentional blink remains unknown. We combine model-based psychophysics, magnetic resonance spectroscopy, and diffusion-weighted imaging to address this question. Our findings indicate a strong and selective link between structural and pharmacological markers in the rPPC and one specific subcomponent – target detection deficits – of the attentional blink.



Motion-Induced Blindness: A Comparative Analysis of Photopic vs. Scotopic Vision

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Abstract

Motion-induced blindness (MIB) was studied under photopic and scotopic conditions using zero, negative (decrement), and positive (increment) contrast valance motion masks. Results showed that the decrement mask led to earlier disappearances and longer total disappearance times under photopic conditions. In contrast, mask types had negligible effects under scotopic conditions, revealing the limitations of rod-based motion detection and motion perception in dim light that led to Troxler fading. These findings suggest that MIB is more sensitive to luminance variations in well-lit environments and highlight the limitations of rod-based motion detection in low-light conditions, with implications for understanding visual processing in dim environments.

Keywords- motion-induced blindness, Troxler fading, photopic, scotopic, ON-channel, OFF-channel.

Motion-induced blindness (MIB) and Troxler fading are two phenomena that offer deep insights into the complexities of visual perception and the underlying neural mechanisms. MIB, first described by Grindley and Townsend (1965), involves the intermittent disappearance and reappearance of stationary objects when surrounded by a moving pattern against a static background, underscoring the complex interplay between attention, perception, and neural processing (Bonneh et al., 2001). Troxler fading, discovered earlier in 1804, similarly involves the vanishing of visual stimuli from awareness when fixed upon, revealing the adaptive nature of sensory processing (Gorea & Caetta, 2008). Both phenomena collectively facilitate the understanding of how the visual system manages continuous information and adjusts to sustained stimuli and are mediated by complex neural circuits involving both cortical and subcortical structures, which share underlying mechanisms such as neural adaptation, where a decrease in the response of neurons to unchanging stimuli leads to perceptual fading. Martinez-Conde et al. (2004) showed that fixational eye movements such as microsaccades prevent visual fading by refreshing the retinal image, emphasizing the brain's adaptability.

MIB involves several neural mechanisms, including boundary adaptation, interhemispheric rivalry, and selective attention (Desimone & Duncan, 1995). Research has shown that this results from neural competition between areas processing the stationary target and the moving mask, associated with the interactions between the ventral and dorsal streams, leading to decreased activity in the ventral cortex and increased activity in the dorsal cortex during target disappearance (Donner et al., 2008). The ventral stream, primarily responsible for object recognition and form representation, extends to the temporal cortex. The dorsal stream, involved in motion detection and spatial localization, extends to the parietal cortex. Rod-dominated scotopic vision, which is highly sensitive to light, has lower spatial resolution and slower response times compared to cones-dominated photopic system (Rodieck, 1998), affects motion perception and the ability to detect stationary objects. In low-light situations, fast-moving objects appear slower (Kenhub, 2023) and are less efficiently detected, which is crucial for activities such as night driving. This selective activation and suppression across different parts of the visual cortex suggests that MIB serves as a mechanism to reduce sensory overload by filtering out non-essential visual cues.

Troxler fading primarily involves the temporal dynamics of neural adaptation within the retina and visual cortex, particularly in areas associated with peripheral vision, where constant stimuli lead to reduced neural activity, causing stationary objects to fade from perception (Bonneh et al., 2014). This adaptation is more pronounced in peripheral vision, which is less effective at detecting fine details and changes compared to central vision (Anstis, 1996). Studies using fMRI and other neuroimaging techniques have identified specific cortical areas that exhibit decreased activity corresponding to the perceptual disappearance of stimuli, highlighting the role of sustained attention and the brain's adaptability to unchanging information (Donner et al., 2008).

The contributions of ON-center and OFF-center cells in the retina further explain the neural basis of MIB and Troxler fading. ON-center cells depolarize in response to light increments, while OFF-center cells depolarize in response to light decrements, and these opposite responses to increases and decreases in light form a fundamental component of the visual system's ability to process contrast and detect edges. Photoreceptors reduce glutamate release when exposed to light, leading to the hyperpolarization of OFF bipolar cells (decrement response) and depolarization of ON bipolar cells (increment response). Rod bipolar cells, which are exclusively ON-type, dominate in low-light conditions, enhancing the detection of light increments but are less effective for decrements (Feng et al., 2016; Sharpe et al., 1999).

At the cellular level, these pathways remain segregated from the retina to the visual cortex (V1) (Pandarinath et al., 2010). This separation allows the visual system to efficiently process contrasts and changes in luminance (Dolan & Schiller, 1994). For example, Dolan and Schiller (1994) conducted experiments using 2-amino-4-phosphonobutyrate (APB) to block the ON channels in monkeys. They found that blocking ON channels significantly reduced the perceived brightness of incremental stimuli, demonstrating the critical role of ON pathways in visual perception. In the context of MIB and Troxler fading, this differential involvement of the ON and OFF pathways highlights their distinct roles in shaping our visual experience under different luminance conditions (Schölvinck and Rees, 2009).

The interplay among MIB, Troxler fading, the ON/OFF pathways, and the photopic-scotopic system forms the foundation of our study. Previous research has focused primarily on MIB under photopic conditions, where both ON and OFF pathways are active (White et al., 2023). However, under scotopic conditions, where rod bipolar cells and the ON pathway predominate, the mechanisms of MIB and Troxler fading may differ significantly. Scotopic vision alters the perception of motion and speed. Detection thresholds for coherent motion increase with decreasing light levels (Billino et al., 2008) and the perceived velocity of rod-mediated stimuli was reduced by approximately 20% compared to cone-mediated stimuli at low temporal frequencies (Gegenfurtner et al., 2000), highlighting the limitations of rod-based motion detection.

Under photopic conditions, we hypothesize that MIB will occur with both positive and negative contrast valences due to the active involvement of both ON and OFF pathways. Conversely, under scotopic conditions, we expect MIB to predominantly occur with positive contrast valence due to the dominance of the ON pathway and the limitations of rod-based vision in detecting decrements. Primarily, before experimenting, we also hypothesized that there would be little disappearance with zero contrast valence, i.e., no motion mask, under scotopic conditions relative to when the motion mask was visible.

METHODS

Participants. Twelve volunteers (six males and six females) from the UNH community participated in the study, all with normal or corrected-to-normal vision. Informed consent was obtained from all participants according to the University of New Hampshire Institutional Review Board policies.

Apparatus. The experiment was conducted using MATLAB (v. R2023a, MathWorks) with Psych Toolbox extensions on a 21.5-inch iMac Pro. The monitor's resolution was set to 1,920 × 1,080 pixels, and gamma correction ensured linear gray levels. Two light levels were used: photopic and scotopic. Scotopic conditions were achieved using 6 sheets of ND9 filters, reducing luminance by 5.97 log units. Luminance was measured using a photometer (MINOLTA LS-110).

Stimuli. The stimuli included three types of motion masks: positive contrast (increment), negative contrast (decrement), and zero contrast (no mask). The central stimuli included four increment fixation dots creating an imaginary square with a hollow center and four target dots positioned at the corners, 15 degrees from the center. To account for the blind spot, corresponding to the optic disc where there are no photoreceptors, the positioning of the stimuli was carefully adjusted to avoid unintentional loss of visual information due to this natural gap in the visual field. Additionally, 2500 randomly moving mask dot elements were presented on a gray screen with a luminance of 107.5 cd/m². Motion-mask dots measured 0.070 degrees of retinal angle, while target dots were 0.240 degrees. A chin rest maintained a 1-meter viewing distance.

Stimuli in Photopic Conditions. The luminance for increment and decrement masks was 283.7 cd/m² (Weber contrast 1.639) and 0.28 cd/m² (Weber contrast -0.997), respectively.

Stimuli in Scotopic Conditions. ND filters reduced the background luminance to 1.152×10^{-4} cd/m². Increment mask elements had a luminance of 3.040×10^{-4} cd/m² (Weber contrast 1.639), and decrement elements had 3.000×10^{-7} cd/m² (Weber contrast -0.997).

Independent and Dependent Variables. Independent variables: mask contrast valence (positive, negative, zero – i.e., no mask) and luminance level (photopic, scotopic). Dependent variables: total disappearance time, time to first disappearance, and the number of disappearances. Each participant completed 60 trials per session (20 trials per mask condition) under both photopic and scotopic conditions, totaling 120 trials.

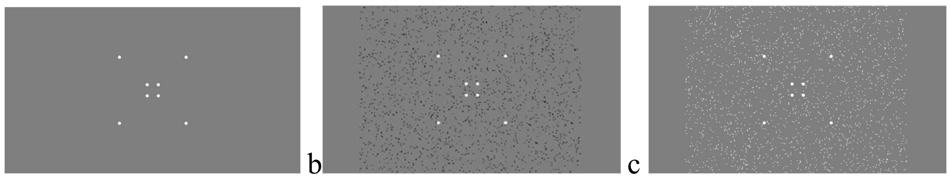

Figure 1: Condition without any mask; only increment targets are present (a), condition with decrement mask and increment target (b), and condition with increment mask with increment target (c).

Procedure. Participants were fixated on a central point surrounded by four target dots and a moving dot mask. In scotopic conditions, participants dark-adapted for 45 minutes before 20-second trials, with 20-second adaptation periods between trials. In photopic conditions, a 5-minute adaptation period was used without ND filters. Participants pressed the space bar when a target disappeared and released it upon reappearance, maintaining fixation throughout.

RESULTS

Preliminary tests suggested pooling the Trial variable, resulting in three two-way randomized-block factorial designs, each dependent variable (Kirk, 2013). Significant effects were explored with Westfall *a posteriori* pairwise comparisons. Significant main effects are not reported given significant interactions.

Time to First Disappearances under Photopic and Scotopic Conditions

An interaction between mask type and luminance level was observed ($F(2, 22) = 4.51$, GG $\epsilon = 0.849$, Adj-p = 0.0302, Partial $\omega^2 = 0.346$; Holm-Šidák $\alpha_{test} = 0.0500$). The difference between the Decrement Mask and No Mask decreased significantly in the Scotopic condition relative to the Photopic condition (mean change = 5.57 seconds, $t(11) = 3.03$, $p = 0.027$).

There were no overall average differences between the Photopic and Scotopic conditions ($F(1, 11) = 0.003$, NS). The interaction among subject, mask type, and luminance level was significant ($F(22, 1368) = 4.28$, $p = 1.72 \times 10^{-10}$, Partial $\rho = 0.354$; Holm-Šidák $\alpha_{test} = 0.0257$).

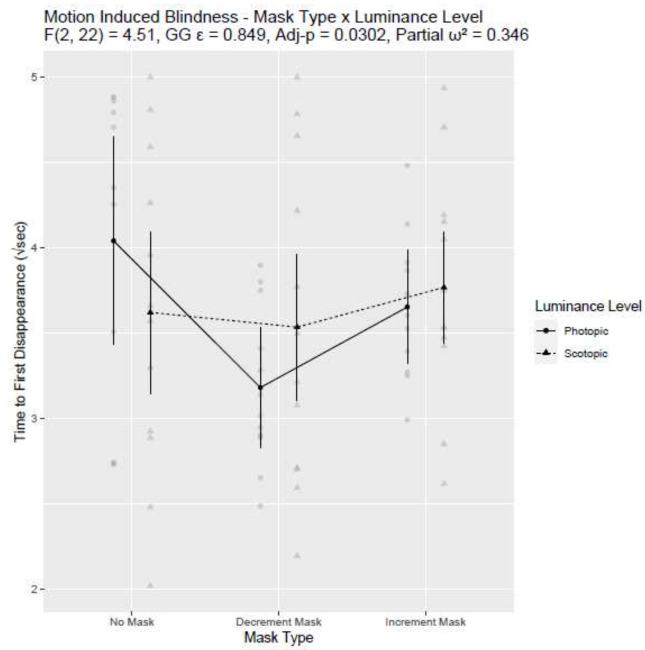

Figure 2: Mask Types x Luminance Level Means Time to First Disappearance with 95% CI.

Number of Disappearances under Photopic and Scotopic Conditions

An interaction between mask type and luminance level was observed ($F(2, 22) = 7.65$, GG $\epsilon = 0.956$, Adj-p = 0.0035, Partial $\omega^2 = 0.432$; Holm-Šidák $\alpha_{test} = 0.0500$). The difference between the Decrement Mask and No Mask increased significantly in the Photopic condition relative to the Scotopic condition (mean change $\log_{10} = 0.243$, $t(11) = 3.834$, $p = 0.007$, original mean change = 1.377 disappearances).

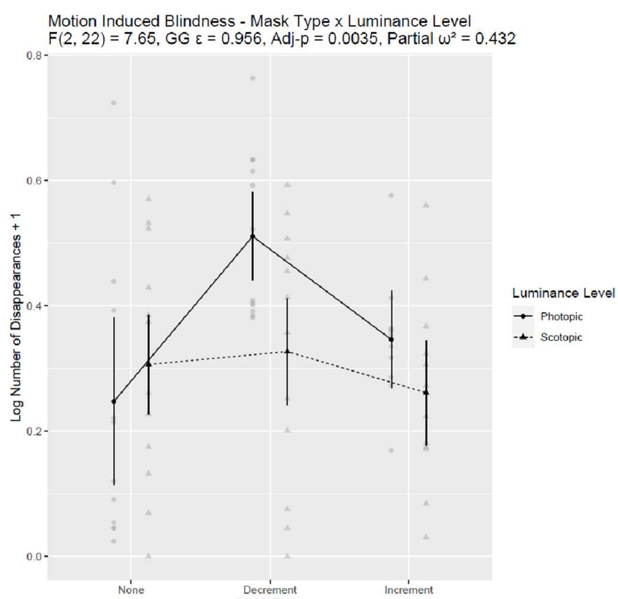

Figure 3: Mask Types x Luminance Level Means Number of Disappearances with 95% CI.

The interaction among subject, mask type, and luminance level was significant (F(22, 1368) = 4.95, $p < 0.001$, Partial ρ = 0.396; Holm-Šidák α_{test} = 0.0170).

Total Time of Disappearances under Photopic and Scotopic Conditions

An interaction between mask type and luminance level was observed (F(2, 22) = 7.2441, GG ϵ = 0.87527, Adj-p = 0.00583, Partial ω^2 = 0.303; Holm-Šidák α_{test} = 0.0257). The difference between the Decrement Mask and No Mask increased significantly in the Photopic condition relative to the Scotopic condition (mean change $\log_{10}$ = 0.255 seconds, t(11) = 4.015, p = 0.00521, original mean difference = 1.398 seconds).

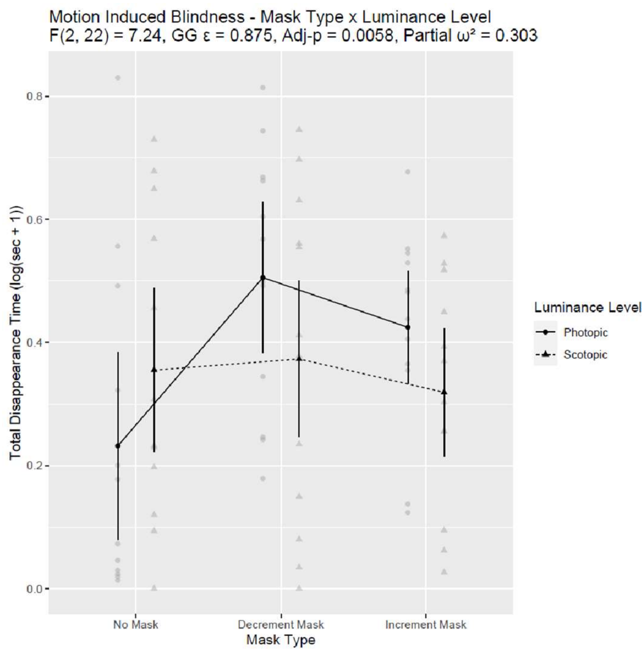

Figure 3: Mask Types x Luminance Level Means Total Disappearance Time with 95% CI.

The interaction among subject, mask type, and luminance level was significant (F(22, 1368) = 4.312, $p = 1.35 \times 10^{-10}$, Partial ρ = 0.303; Holm-Šidák α_{test} = 0.0257).

The effects of motion mask type on MIB suggest that their influence is more pronounced under photopic conditions, whereas under scotopic conditions, these effects are diminished. This suggests that MIB is more sensitive to variations in mask type when the visual environment is well-lit and less so in dim lighting. This difference can be attributed to the varying functions of rods and cones.

The subject-wise analysis and their verbal responses indicate variability among subjects' responses to changes in mask types and luminance levels as well as their motion perception under low light levels. Seven of the twelve subjects followed the expected MIB pattern during photopic, but only three did under scotopic conditions - few subjects exhibited the expected results under scotopic conditions.

DISCUSSION

Under photopic conditions, MIB was more pronounced due to the active ON and OFF pathways and high spatial resolution of cones. The difference in MIB with different mask types under photopic conditions can be attributed to the differential activation of ON and OFF pathways. The decrement mask (negative contrast) primarily stimulates the OFF pathway, while the increment mask (positive contrast) stimulates the ON pathway. This differential stimulation affects the competition between the moving mask and stationary target, leading to varying MIB effects. The increment mask's reduced effect relative to the decrement mask in the photopic condition may be due to already highly active ON pathway's response to the increment targets. Thus, the competition between the mask and the target is not as strong as with the decrement mask, leading to lesser MIB effects. The Decrement Mask led to earlier disappearances and increased disappearance time. In scotopic conditions, MIB effects were less pronounced, highlighting the limitations of rods in detecting motion and the increased occurrence of Troxler fading. Subjects often missed the motion masks in dim light, suggesting differential processing of static and moving objects.

Rods, predominant in low-light conditions, are highly sensitive to light but less effective at detecting fine details and rapid movements (Burkhardt, 2011; Kenhub, 2023; Rodieck, 1998), which diminished impact of motion masks and the enhanced Troxler fading in scotopic trials.

To better measure MIB at scotopic levels, increasing the size of targets and motion mask elements, slowing down the speed of the moving mask, and extending trial durations are recommended. Future research should explore the impact of varying speeds of motion masks on MIB under different luminance conditions. Additionally, investigating the role of different spatial frequencies and their interaction with speed and luminance could reveal further complexities in visual perception and neural adaptation mechanisms. Understanding these interactions can inform the design of visual aids and training programs for low-light environments and contribute to the broader field of visual cognition and sensory processing.

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Additional Information: Please click here

The Effects of Contrast on Motion Induced Blindness and Perceptual Filling-In

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Abstract

In visual perception research, two phenomena are of great interest: motion induced blindness (MIB), where a motion mask causes a distinct target in the peripheral field to perceptively disappear, and perceptual filling-in (PFI), where a target in the periphery doesn't match the area surrounding it, and surrounding movement causes the target to disappear into its surround. The common mechanism hypothesis is the widely theorized idea that the neural mechanisms that cause these phenomena are the same. Contradictory conclusions in literature regarding the effects of low contrast luminance on MIB and PFI have left room for clarification on whether effects of contrast support the common mechanism hypothesis. This study examines the impact of contrast luminance between a target and its background in both MIB and PFI. Results show that the total disappearance time is significantly greater at low luminance contrast decrements for MIB than for increments relative to high contrast. PFI shows no significant differences between any of the variables, which contrasts with results from MIB; differences between results for MIB and PFI do not support the common mechanism hypothesis.

Keywords- Motion Induced Blindness, Perceptual Filling-In, Contrast Valence, Common Mechanism Hypothesis.

INTRODUCTION

Motion induced blindness (MIB) is a phenomenon that occurs when normally sighted observers experience a temporary visual disappearance of a stationary target in the observer's periphery when in the presence of a motion "mask" (Bonneh et al., 2001) (see Fig. 1). This is a phenomenon that can be experienced in everyday life when driving in heavy rain or snow; when a car in the distance is coming towards a driver so that the car is in their periphery, the rain or snow can act as a motion mask, and the oncoming car can disappear from the driver's view, as it will be functioning as the peripheral target.

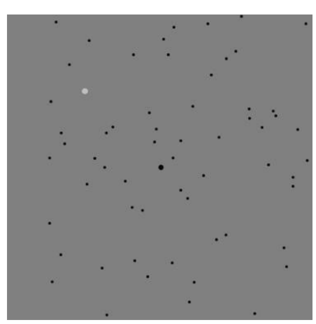

Figure 1: a standard MIB display with a motion mask (black dots across the screen) and a target (light gray dot in the top left corner).

Perceptual filling-in (PFI) is a similar phenomenon, where an area with a lack of visual input will be filled in by surrounding stimuli (Komatsu, 2006; Hsu et al., 2004). A common example of PFI is the blind spot, an area of the retina with no sensory cells that creates a hole in our visual field that is constantly being filled in with our surrounding visual input (see Fig. 2). Another example of PFI is seen in scotomas, which is an abnormal partial loss of vision or blind spot in someone's visual field- these are typically indicative of serious optical disorders, including macular degeneration. Someone with a scotoma could experience PFI without noticing, which can lead to late-stage diagnosis (Komatsu, 2006).

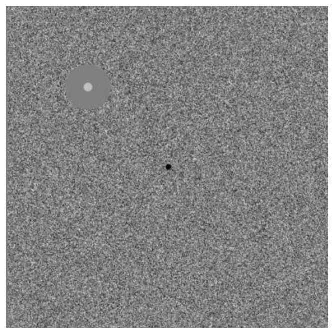

Figure 2: an example of a PFI display, with a field of dots that change luminance rapidly to create a static-like effect, and a light gray target in the top left which will fade into the gray surrounding zone.

The mechanisms by which MIB and PFI occur are not well understood, but one prominent theory is the common mechanism hypothesis; due to the similarity in the nature of these two phenomena and the relationship between them, it is suggested that one common neural mechanism or pathway is responsible for both MIB and PFI (Hsu et al., 2006). However, other studies have since questioned this hypothesis. For example, when binocular rivalry is induced (two separate images being shown to each eye to make perception differ between them) in MIB and PFI, the results for each phenomenon were not similar, meaning that a common mechanism was not used for both (White et al., 2021).

In MIB and PFI, when the contrast of the target relative to its surroundings is changed, it has been observed that the target's disappearance and the interval of disappearance are affected. However, there have been contradictory results for what exactly these effects are (Hsu et al., 2004; Bonneh et al., 2001). Our goal was to clarify previous incongruities that pertain to the occurrence of MIB and PFI under the different conditions of contrast between a target and its background. Relevant previous literature includes studies by Bonneh et al. (2001) and Hsu et al. (2004). In the 2001 study, Bonneh et al. show that there is a greater frequency of target disappearance the greater the target luminance contrast becomes (Bonneh et al., 2001). Similar to this study, Hsu et al. present results that show increased frequency in MIB occurrence at high contrast, but increased frequency in MIB occurrence at low contrast luminance, where the luminance of the target is close to the background, is also observed. This same study also observed the effects of contrast on PFI; PFI only showed increased occurrence at high luminance contrast (Hsu et al., 2004). We aimed to create a display system that combines the approaches of these two studies and focus on whether the frequency of occurrence of MIB and PFI is impacted by low luminance contrast.

Based on previous research, the contrast in luminance between a target and the background has an impact on occurrence of MIB and PFI at higher contrast, but impact of low contrast is less clear. Hsu et al. (2004) concluded that their study supported the common mechanism hypothesis, but the different patterns of interaction of low contrast luminance in MIB and PFI in their study do not support the hypothesis. If we take the common mechanism hypothesis as true, which states that the neural pathways that cause these phenomena are the same, and consider the results of the Bonneh et al. study (2001) and Hsu et al. study (2004), which does not show increased MIB or PFI at low contrast, it would be expected that there should not be an association between low contrast luminance and MIB and PFI occurrence, and that the pattern of interactions for both phenomena should be the same.

METHODS

Participants:

For both MIB and PFI displays, six and seven participants were recruited, respectively. Participants had normal or corrected to normal vision. They signed informed consent forms, and the study was approved by the University of New Hampshire Institutional Review Board.

Apparatus and Stimuli:

Stimuli were coded in *MatLab* (MathWorks v. 2023b) using the *PsychToolBox* extension. The background was kept at a constant 125 cd/m^2. Participants used a head stabilizer and kept at a one-meter distance from the screen displaying the stimuli.

To transition the system more easily from an MIB display to a perceptual filling-in (PFI) stimulus that has the least variability possible, the density of dots in the MIB motion mask was set to 60 dots for each trial, which is increased compared to the stimuli of previous studies (Hsu et al., 2004). The only variable that was manipulated was the target dot; the motion mask was kept at a constant 25 cd/m^2 (black) in MIB displays, and the stationary mask in PFI stimuli constantly alternated between multiple contrast levels between 25-225 cd/m^2 to create a "twinkling" effect. The target dot was presented at four different contrast levels; two decrements, 25 and 75 cd/m^2 (Weber contrast of -80% and -40% below the background value), and two increments, 175 and 225 cd/m^2 (40% and 80% above the background). The target dot stayed in the upper left quadrant of the screen throughout the trials. These parameters were consistent for both MIB and PFI stimuli.

Procedure:

Participants were seated in a dark room with a head stabilizer at a one-meter distance from the screen displaying the stimuli. They were given a three-minute adjustment period in the darkness before the session started. MIB and PFI were split into two separate sessions; in each session, there were twenty trials for each of the four contrast levels, resulting in eighty trials total. These trials were displayed for a total of twenty seconds, and there was a ten-second adaptation period between each trial.

To collect data, participants were instructed to indicate the disappearance of the target using a spacebar key on a provided keyboard; this included holding down the spacebar the entire time a target had faded from their vision each time it disappeared in a trial, and releasing the spacebar when it came back into view.

RESULTS

Three dependent variables were measured under MIB and PFI: number of disappearances or filling-in events, the time to the first disappearance or filling-in, and the total disappearance time or time filled in, respectively. For all three dependent variables in each condition, data were analyzed as a three-way randomized-block factorial design using trial (one to 20), target contrast valence (increment or decrement), and Weber contrast (40% or 80%; Kirk, 2013, Sec. 10.5-7) as independent variables. Given the three dependent variables were correlated a Holm-Šidák procedure was used to maintain a familywise type I error probability of 0.05 (Kirk, 2013, Ch. 8). For the dependent variables to approximate a normal distribution, log(time to first disappearance + 1) (MIB), log(number of filling in events + 1), log(time to first filling in + 1), and log(time filled in + 1) (PFI) were analyzed along with the remaining dependent variables that were not transformed. Analyses were conducted using *R* version 4.2.3.

Subjects differed for all dependent variables, as transformed (number of disappearances; $F(5, 395) = 56.6$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.410$; Holm-Šidák $\alpha_{test} = 0.0170$, or filling-in events; $F(6, 474) = 51.4$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.387$; Holm-Šidák $\alpha_{test} = 0.0257$, the time to the first disappearance; $F(5, 395) = 27.6$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.250$; Holm-Šidák $\alpha_{test} = 0.0257$, or filling-in; $F(6, 474) = 46.9$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.364$; Holm-Šidák $\alpha_{test} = 0.0500$, and the total disappearance time; $F(5, 395) = 20.6$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.396$; Holm-Šidák $\alpha_{test} = 0.0500$ or time filled in; $F(6, 474) = 51.8$, $p < 2 \times 10^{-16}$, Partial $\rho = 0.388$; Holm-Šidák $\alpha_{test} = 0.0170$).

No significant effects were observed as indicated by the Holm-Šidák procedure. However, three effects were significant at the 0.05 level. Increment targets disappeared more often than decrement targets during MIB ($F(1, 5) = 8.69$, $p = 0.0320$, Partial $\omega^2 = 0.390$; Holm-Šidák $\alpha_{test} = 0.0170$; Figure 3).

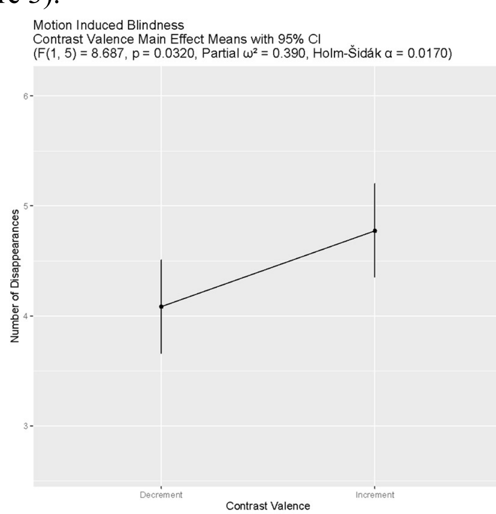

Figure 3: Effect of contrast valence on number of disappearances.

Decrement targets disappeared for longer than increment targets at 40% contrast than at 80% contrast ($F(1, 5) = 10.13$, $p = 0.0245$, Partial $\omega^2 = 0.603$; Holm-Šidák $\alpha_{test} = 0.0170$; Figure 4).

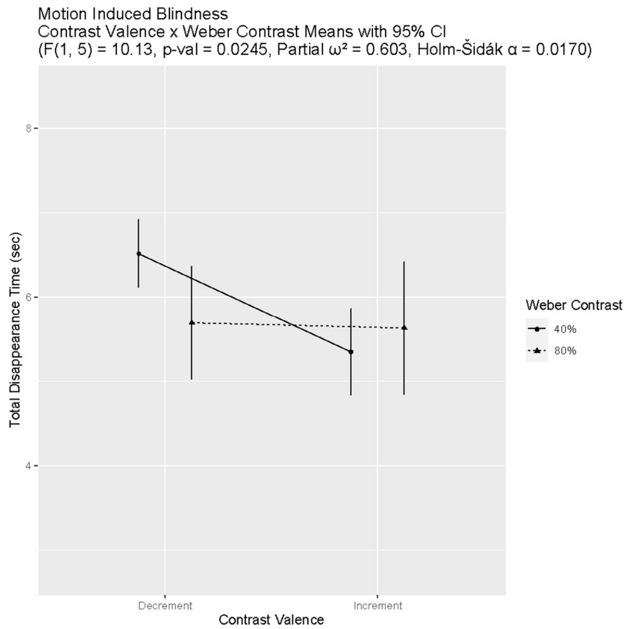

Figure 4: Contrast valence by Weber contrast interaction for total disappearance time.

However, that relationship varied across trials ($F(19, 95) = 1.801$, $p = 0.0335$, Partial $\omega^2 = 0.119$; Holm-Šidák $\alpha_{test} = 0.0170$; Figure 5).

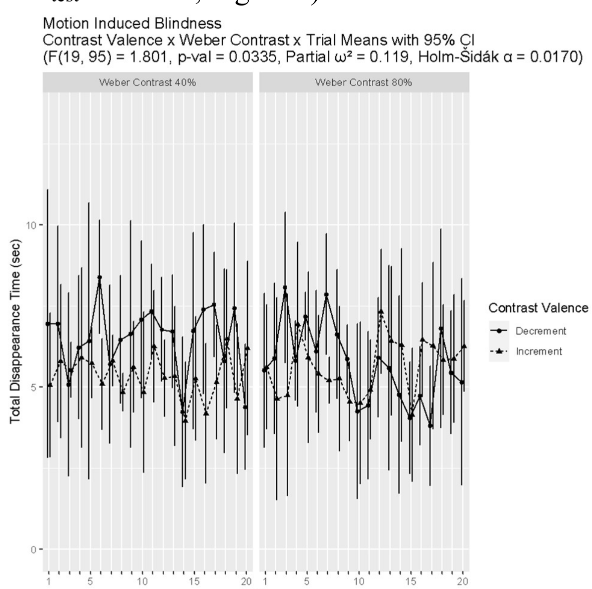

Figure 5: Contrast valence by Weber contrast by trial interaction for total disappearance time.

No other effects were found even at the 0.05 level under MIB or PFI.

DISCUSSION

This study aimed to clarify inconsistencies in previous literature regarding the effects of contrast on MIB and PFI occurrence. It was expected that there would be significance only at high contrast luminance based on results from the foundational studies; however, significance was only found at low contrast luminance for MIB. In MIB, it was observed that low contrast luminance at decrements created longer and unwavering fading duration, but incremental contrast levels, especially at low contrast, gave shorter and more frequent disappearances. No PFI effects were found. These results indicate that when objects in our visual field have low levels of contrast between them, longer and unwavering visual disappearances such as MIB are more likely to occur; when objects in our visual field have high contrast between them, the same visual disappearances will occur in short “bursts”.

These results are contradictory to previous studies by Bonneh et al. (2001) and Hsu et al. (2004), and to the current understanding of the mechanisms involved in MIB and PFI proposed by Hsu et al. (2006). Since MIB and PFI displayed different patterns of interactions among variables, these results do not support the idea of a common mechanism between the two phenomena. There is a possibility that MIB and PFI could be sharing one mechanism and utilizing it differently, which would also produce different patterns of interactions, but this requires further research to fully understand. Assuming the results of this study are valid, however, our study implies that there are two separate neural pathways that process MIB and PFI instead of one common pathway. Furthermore, as mentioned before, our results do not agree with previous studies that showed higher amounts of disappearance when objects in the visual field have high contrast between them. Instead, our results indicate that low contrast decrement variables have the longest duration of disappearance.

One potential limitation to this study could be that within- and between- On-Off channel manipulations for the target and the mask were not implemented; previous studies by White et al. (2020, 2021) examined the effects of On-Off channel manipulations between variables with MIB stimuli and found a higher frequency of disappearances for MIB with within-channel manipulations. Since the mask remained at a constant 25 cd/m^2, a high contrast decrement, there is a possibility that results may have been influenced by not keeping contrast levels consistent between the target and the mask. This adjustment will be made in a replication study. It also would increase the power of the study if the sample size was increased in the replication study; to achieve a power of 80%, we would need a total of eight participants for both MIB and PFI.

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The Environment as a Factor: Investigating the Impact of Environment on Cognition with VR

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Our surroundings can influence our ability to process and remember information. Factors such as ambient lighting, spatial configurations, noise, and distractions provide multimodal sensory input that affects our focus and task performance in daily life. Traditional experimental research seeks to minimize these effects by using minimalistic stimuli and laboratory environments based on two-dimensional computer screens. However, recent developments in Virtual Reality (VR) technologies have brought a paradigm shift to this research by allowing the creation and adjustment of virtual environments with control and accuracy. By mimicking natural visual perspective projection, these experiments can be tailored to investigate stimuli within context, opening new possibilities for research. We present evidence from experiments that compared the effects of the traditional mode of task presentation (2D screen) to VR (head-mounted display) on participants' performance, reaction time, and accuracy in well-established experimental psychology tasks, i.e., the Lexical Decision, Flanker, and Serial Recall tasks. All tasks had congruent results between presentation modes, pointing to the reliability of VR as a method, as findings reproduced typical patterns found in attention, memory, and word recognition research. Additionally, we varied stimuli presentation in terms of the number of dimensions (2D and 3D), level of contrast (low and high), and virtual environment conditions (rainy and sunny environment). No significant differences between 2D or 3D stimuli presentation were found. However, the effects of low contrast and rainy weather impacted performance. These results are discussed in the context of each design's limitations and chosen parameters. Altogether, this research is a step towards approximating laboratory conditions to ecological settings using VR by reproducing classical cognitive tasks in VR, integrating stimuli into a scene, and varying scene characteristics by imitating real-world weather variations.

Key words: Virtual Reality; Ecological Validity; Human Factor; Flanker; Lexicality; Serial Recall

Role of Anticipation in Improving Visuo-Proprioceptive integration and Enhancing User-Experience in Virtual Reality

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Introduction

Virtual reality is a computer-generated simulation of a three-dimensional environment that allows users to interact. In research VR is used to study memory, attention, decision-making, spatial navigation, and social interactions. VR holds promise in various applications dealing with complex spatial problems, such as design, architecture, and city planning, for transfer of training in areas like spatial navigation, medical simulation, and rehabilitation.

Virtual reality (VR) is still in its early stages of development, two primary aspects people concentrate to improve the sense of immersion and user experience are experiential fidelity (how real the simulation feels) and action fidelity (how well users' actions align with real life behaviour) (Flach et al., 1986). Most of the work to improve sense of immersion concentrate on improving experiential fidelity and action fidelity is given minimal importance. The action fidelity concentrates on enhancing subjective interaction and improving sense of agency, which plays a major role in improve the sense of immersion and user experience. In this paper we are going to concentrate on one aspect called sensory motor integration, especially vision and proprioception integration in virtual environment to improve action fidelity in VR.

Vision and proprioception integration in VR:

Vision provides information about the external world, including spatial features and targets. Whereas proprioception is our body's ability to sense movement, action, and location, it allows you to know where your body parts are in relation to each other and helps coordinate movements. When we perform actions, such as grabbing a book from a shelf, we see and intuitively sense our hand position. However, the sensory feedback from the retina and the proprioceptive receptors takes some time to reach the central nervous system (CNS), resulting in a lag between the actual hand position and our perception. An estimate for proprioceptive sensory delays is 50- 60 millisecond (Mima et al., 1996, Alary et al., 1998), and vision is 120 milliseconds (Lamme et al., 1998, Lamme, 2000).

To compensate for these delays, brain uses predictive models to anticipate the consequences of motor actions and motor commands. We perform the action based on the anticipated information issued by the brain to initiate movements (Adams et al., 2013.L). The integration of vision and proprioception happens according to the maximum likelihood principle (le Berger and Wolpert, 1988). This principle suggests that our brain interprets sensory input based on what is statistically most probable in a given context. Even when we lack information from a single sensory modality (such as visual input), according to the maximum likelihood principle our brain optimally combines available sensory cues. In the absence of vision, proprioceptive information becomes more dominant.

As a result, the perceived position of shift in the direction of proprioception. The vision and proprioception integration in virtual world is not similar to that of the real world. The VR headset often introduces a new delay in vision called as motion to photon latency refer to the figure 1. This lag is estimated to be around 20-40 milliseconds.

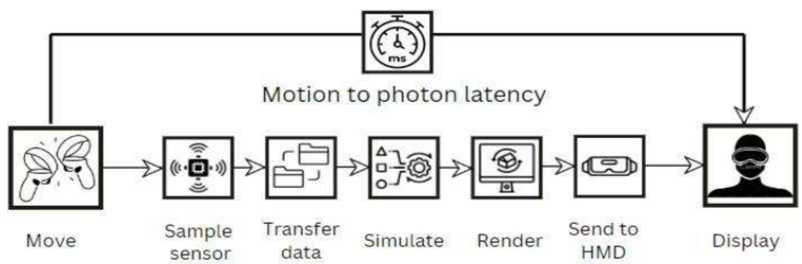

FIGURE 2.1: The figure illustrates various processes involved in preparing a frame and presenting it on the HMD, contributing to motion-to-photon latency.

Figure 1: The figure illustrates processes involved in preparing a frame and presenting it on the HM, contributing to motion to photon latency

In the real world, proprioception leads vision by approximately 40-50 millisecond. However, in virtual reality, an additional visual lag of 20-30 millisecond can extend this led to 60-80 millisecond. This increased delay can result in unusual behaviour and potentially cause eyestrain, headaches, motion sickness symptoms, disruptions in hand- eye coordination, locomotory and postural instability, misperceptions, contradicting expectations, errors in task execution and degraded task performance.

In fact, this is the reason most of the training in VR is not transferrable to real world. They are encoded differently in virtual world adjusting itself for the delays compared to the real world. One way to address these challenges is by using adaptation strategies or improving the technology itself.

Currently, efforts primarily focus on enhancing hardware and software, such as using faster computers and better display systems. However, some issues, like delays in feedback and simulator sickness caused by conflicting sensations, still need solutions despite advancements in technology. Moreover, the high costs of new technology can limit its widespread use. While there is ongoing research on adaptation strategies, relying too heavily on them might have unexpected effects, such as experiencing VR effects even in real life. Upon leaving the VR environment, our brains may need to recalibrate to real-world conditions. These aftereffects can lead to altered hand eye coordination, causing users to misjudge distances or reach inaccurately once back in the physical world. The duration of exposure to the VR environment influences the persistence of these effects (Hettinger, 2003).

Rather than focusing solely on hardware and software improvements or adapting to the VR environment, we can employ an approach related to psychological principles called anticipation.

The need for brain adaptation arises because the anticipated visual input does not match the received input. In our proposed solution, we use prediction algorithms to forecast the next frame a few milliseconds ahead based on the user's current actions and coordinates. This prediction compensates for delays in preparing the next frame, allowing us to render the frame anticipated by the user. As a result, there is no need for adaption and the brain requires minimal free energy to update its prediction, enhancing the sense of presence and performance in the VR environment.

Gap in the literature:

A study on impact of the predictions on the motion-to-photon latency is done by (Warburton, 2023) showed that motion prediction algorithms where the prediction is two frames ahead accounted for inherent delays, the effective latency was functionally reduced to 2–13 millisecond. Importantly, this reduction occurred within approximately 25–58 millisecond of movement onset. While previous work has introduced prediction algorithms in VR, there remain unanswered questions. We don't yet know the optimal number of frames to predict in order to create congruent stimuli that result in seamless integration of vision and proprioception. Additionally, at what point does the disparity between predicted visual input and actual proprioceptive feedback become significant enough to cause incongruence? The impact of these predictions on user perception and performance in VR, particularly under conditions of current system delays, remains underexplored.

To address these issues, we focus on a simple hand-grabbing and moving task. In such tasks, the participant's next action is highly predictable. By using a Recurrent Neural Network (RNN) model, we predict future frames and render them in the current VR environment. This approach aims to examine how predictive modelling can enhance sensory integration and improve user experience and performance in VR. For this study, we propose an experiment to investigate the effect of predictive rendering on vision and proprioceptive integration.

Methods

Materials

The experimental setup involved participants sitting in front of a table wearing a VIVE headset and 5DT data glove attached to an HTC Vive wireless controller to their dominant hand. A virtual table was spatially aligned with the physical table at which the participant sat. A cardboard box of length attached to an HTC Vive wireless controller was placed on the table, precisely 37.5 cm from the centre, in line with the centre point either to the right or left depending on the experimental conditions. This box is aligned with a virtual box visible in the virtual environment.

The controller attached to the box ensures that any movement of this box is mirrored by a virtual box. The controller attached to the participant hand tracks the motion and position of the hand. The 5DT data gloves measures bending of the fingers and wrist flexion. The virtual hand that mirrors participants' physical hand in real time is rendered in the VR environment. A virtual grid is positioned at distance of 37.5 cm either to the left or right from the centre making an angle chosen from the set 0°, 45°, -45° with the centre. based on the experimental condition. At the centre of the table, a green-coloured virtual cuboid is placed that served as the start button. Two virtually invisible sensors which can be called as the box sensor and grid sensor, are attached to the box and grid, respectively. The grid sensor detects the box and the box sensor detects the virtual hand when it is in its proximity. The proximity of both the sensors is set to 1 unit scale.

The experiment contains 1 practice block and 3 main blocks, where each main block is divided into 4 sub-blocks. These 13 sub-blocks are situated in 13 different virtual scenes consisted of a virtual table

Experimental Conditions

Condition P0 (Baseline): No manipulation is done. Participants' hands were rendered in virtual reality (VR) at their actual positions without any prediction.

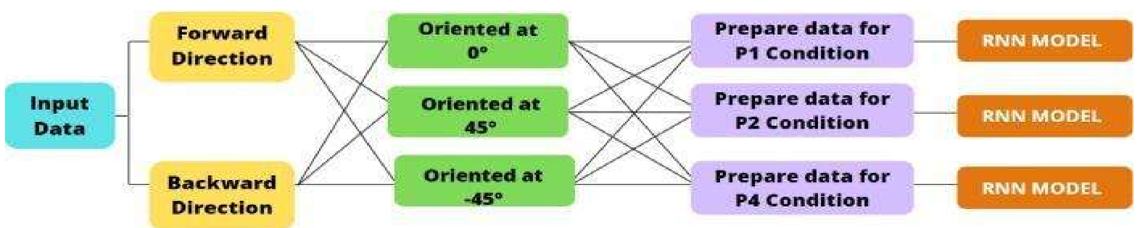

Figure 2: Figure shows the hierarchy of the RNN models trained

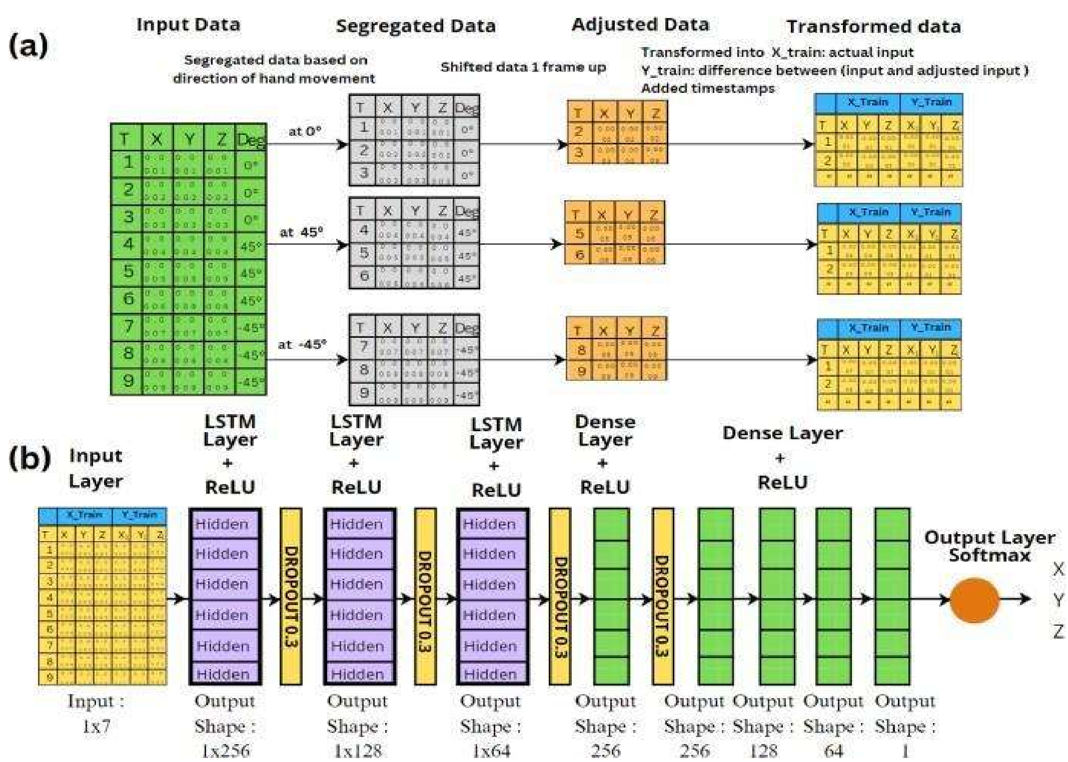

Figure 3: a) Flowchart showing the manipulation performed on the input data. b) Flowchart depicting the architecture of an LSTM model for the offset prediction for 1st frame ahead with input features representing time, X, Y, and Z coordinates. The model includes LSTM and Dense layers with dropout regularization for training stability

Condition P1: An RNN model as shown in Figure 2 and Figure 3, is trained with an input data file of hand positions at various time points, is designed to predict the offset between the current hand position and its position 10 milliseconds ahead. Before rendering each frame of the virtual hand holding the box (on average at every 10 milliseconds), the predicted position of the virtual hand is calculated as the sum of the current physical hand position and the predicted offset. The virtual hand holding the box is then rendered at this predicted position instead of the position provided by the Steam VR algorithm.

Condition P2: Similar to P1, but the hand holding the box was rendered at the RNN-predicted position for the second frame (20 milliseconds) ahead.

Condition P4: Again, the hand holding the box was rendered at the RNN-predicted position, but this time for the fourth frame (40 milliseconds) ahead

Procedure

The practice block comprises 40 trials. During these trials, the position information of the hand holding the box is recorded every 10 milliseconds while performing the task and added to an input data file. This input data file contains the hand position data of all participants. After the 40 trials, a Virtual Experience questionnaire with two questions is presented and answered in the VR environment. After answering the questionnaire, participants are asked to take a break and explore the environment. The green start button is then displayed on the table again, and participants press this button when they are ready to move to the next block. During this time, eighteen separate RNN models are trained, each corresponding to: 2 directions × 3 orientations × 3 conditions.

Each main block contains 40 trials, divided into sub-blocks of 10 trials. Each sub-block represents one of the four conditions (P0, P1, P2, P4). The P0 condition sub-block is a baseline condition where the virtual scene is rendered without manipulation. In Pn conditions (where $n \in \{1, 2, 3\}$), before rendering each frame, the actual hand position is passed to its corresponding RNN model to predict the offset to be added to the current hand position to simulate being n frames ahead. After obtaining the predicted outcome, the virtual hand position is updated by adding the predicted offset to the current position, and it is rendered at this new position. During each trial, the participant needs to pick up the box and place it on the grid, and the reaction time is recorded. After a successful trial, the box turns green and disappears providing visual feedback. Predictive manipulations of the virtual hand stop, and the hand is rendered at its actual position until the next trial begins. After a successful trial, the participant needs to collect a coin placed at the centre of the table to start the next trial. In the next trial, the grid is shifted to the other side of the box, maintaining a distance of 75 cm between them. The process repeats, with the participant performing 10 trials for each sub-block, followed by a questionnaire about their VR experience After answering the virtual questionnaire, participants are asked to take a break and explore the environment.

VR Questionnaire

The following table gives the information about the questions asked as a part of questionnaire in the experiment.

Asked after:	Questions:	Purpose:
practice block	1)Have you experienced virtual reality with a head-mounted display in the past? 2. Did you feel dizzy or off-balance during your interaction with the virtual environment?	These questions assess participants' prior experience with VR and any discomfort during interaction. They help analyse motion sickness in participants.
every block	3. Regarding virtual reality experience, sense of agency, and control across different conditions. 4. How much lag do you think your actions had in VR? 5. How much leading do you think your actions had compared to your proprioception in VR	The first questions assess participants' virtual environment (VE) experience, providing insight into how subjective experiences vary with different manipulations of them virtual hand. Questions 4 and 5 primarily address how rendering the predicted hand affects perceptual experience.
Completion of experiment	How enjoyable did you find the experiment? How immersive did you feel?	These two questions pertain to the interaction and immersiveness experienced by participants during the experiment.

Experimental Design

The experiment is a within-subject 1 x 4 factorial design, with one independent variable - reaction time and the four conditions (P0, P1, P2, P4) are dependent variables. Subject wise mean reaction time was calculated by computing the average of mean reaction time across trials for each condition, which served as the dependent variable. The Outlier criteria was determined as any participant whose any of the mean reach error values fall above Q3 + 1.5 x IQR or below Q1 – 1.5 x IQR (Q3

= Third quartile, IQR =interquartile range). These data points are removed from the further analysis. Following each block, participants were given a questionnaire to assess their virtual reality experience. The subject-wise mean of the scale (ranging from 0 to 4) was determined by calculating the average of answers across trials for each condition, which served as the dependent variable.

Results

A 4 (Conditions: P0, P1, P2, P4) × 3 (Blocks) repeated measures ANOVA was performed to assess their impact on reaction time. The analysis revealed a significant main effect of both ition and block with $P<0.001$ No significant interaction effect between the two factors was present ($P = 0.36$).

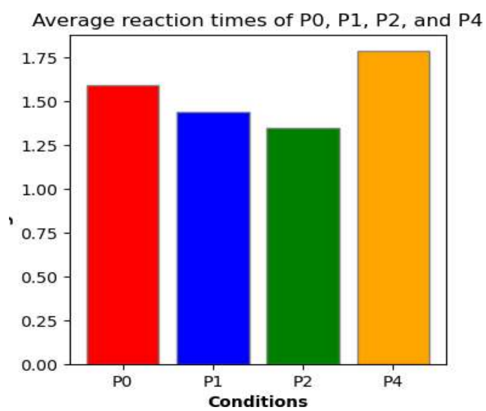

Figure 4: The figure displays the average reaction times of 16 participants across four experimental conditions. The X-axis represents conditions, while the Y-axis represents the mean reaction times.

Post-hoc pair-wise comparisons using Holm-Bonferroni corrected paired t-tests were conducted to analyse the differences in reaction time between each of the four conditions (P0, P1, P2, P4). The results showed significant differences in reaction time among several pairs of conditions. Specifically, reaction times differed significantly between P0 and P, P2 and P4, and P1 and P2, P1 and P4, P0 and P4 with $P<0.001$ suggest that the condition P2 and P4 are significantly different from the other conditions. The order of the reaction times will be as P2<P1<P0<P4. This is clearly demonstrated in Figure 4.1. The average reaction time of P0 = 1595 milliseconds, P1 = 1.436 milliseconds, P2 = 1345 milliseconds, P4 = 1781 milliseconds. The condition P2 gives an advantage of 250 milliseconds compared to the baseline condition.

In the questionnaire analysis, the entire questionnaire is divided into three questions:

1) The first question is about the virtual reality experience, sense of agency, and control across different conditions.
2) The second question concerns the lag experienced while performing actions in VR across different conditions.
3) The third question asks how much the participants felt their virtual hand was leading compared to their real hand.

The analysis for questions Q1, Q2, and Q3 shows a significant main effect with the condition, with $p < 0.001$. The future analysis (refer to Figure 4.2) indicates that the virtual experience, sense of agency, and control remain constant across conditions P0, P1, and P2, but vary for condition P4. Participants experienced more lag in conditions P0 and P1, which are the baseline conditions, and less lag in conditions P2 and P4. Additionally, participants reported that their virtual hand felt like it was leading compared to their proprioception in condition P4.

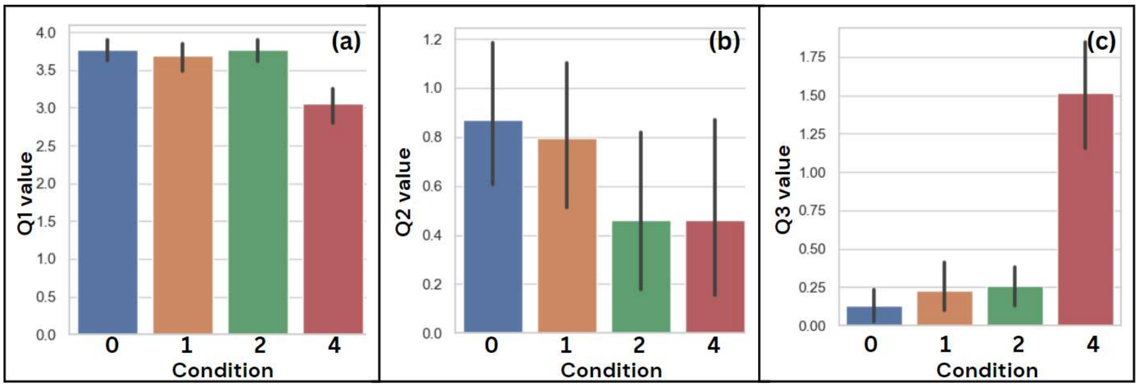

Figure 5: Figure displaying the bar plots values of participants answers to Q1, Q2, Q3 across four conditions P0, P1, P2, P4.

Discussion

The results of the experiment show that reaction time is affected by the experimental conditions (P0, P1, P2, P4). Participants demonstrated faster reaction times in condition P2, where the virtual hand is rendered two frames ahead of their actual hand position. In contrast, reaction times were slower in condition P4 across all participants. This suggests that the anticipated frame for participants might be the second frame. When the anticipation matches the input received, participants did not notice the change in condition P2, maintaining the same sense of self-agency and control as in the baseline condition. However, in condition P4, where the frames are rendered behind their anticipation, reaction time increased and self-agency and control decreased. This further supports that the improvement in the P2 condition is due to the alignment of anticipated input with provided input.

General discussion

In this experiment, we found that predicting the position of the virtual hand by rendering it two frames, or approximately 20 milliseconds, ahead of the actual hand position creates the most congruent stimuli. This results in a seamless integration of vision and proprioception, allowing users to interact more naturally within the VR environment.

However, rendering the virtual hand beyond four frames, or about 40 milliseconds, ahead of the actual hand position creates a noticeable disparity between the predicted visual input and the actual proprioceptive feedback. This discrepancy causes incongruence and reduces the sense of presence and realism in the VR experience. By fine-tuning the prediction to two frames ahead, users' performance in VR can be significantly improved without compromising their sense of agency and control, enhancing the overall user experience.

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Papers and Abstracts for Posters

Temporal Perception and Delay: Mechanisms of Distortion

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Abstract

In the past three decades, significant attention has been paid to understanding temporal processing in humans. It has been shown that different stimulus features affect temporal processing in various ways. In cognitive disciplines such as attention, perception, memory, and time perception, researchers often vary the Interstimulus Interval (ISI) to avoid inherent learning effects that might skew results. However, the influence of ISI on temporal processing remains an open question. Specifically, it is unclear whether variations in ISI can affect temporal judgment, including temporal accuracy (Point of Subjective Equality, PSE) and temporal sensitivity (Difference Limen, DL). This study aims to investigate the influence of ISI on temporal processing for two specific durations: 500ms (Short Delay) and 1000ms (Long Delay). We employed a temporal discrimination task across two different modalities—visual and auditory—to explore any modality-specific mechanisms. In the temporal discrimination task, a standard stimulus with a fixed duration of 500ms was followed by a comparison stimulus with durations ranging from 200ms to 800ms, in 100ms increments. A blank screen served as the ISI, separating the standard from the comparison for durations of either 500ms or 1000ms. We recruited a total of 70 participants from TIET, Patiala, with 35 participants assigned to each task. For the visual task, there were 182 trials in total, and for the auditory task, there were 168 trials in total. The results revealed significant differences in PSE, suggesting an overestimation of duration for long ISI and underestimation for short ISI in both modalities (visual and auditory). Additionally, we observed significant differences in DL, indicating better temporal sensitivity for long ISI and poorer temporal sensitivity for short ISI. These findings are interpreted in the context of the clock mechanism and offer a novel perspective on how the brain might process temporal intervals.

Slower Temporal Productions in Meditation-Like States

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Abstract

Some studies have linked the elongation of time estimation to meditation sessions [1]. One possible reason for this connection is the strong bodily component in time perception and meditation [2]. Based on the Sphere Model of Consciousness [3], we hypothesise a slowing of perceived time in a task with a stronger bodily component. The Breathing group and the Sound group performed three tasks. 38 participants played 6 time durations three times (2, 4, 8, 10, 12, 16, 20, 24, 32s; randomised) during the presentation of Rubin's vase-face illusion. Additional attentional demands were made on participants while performing the temporal production task (TP):

- Baseline: TP while only looking at the stimulus.
- Focused: TP focusing on one facet of the stimulus without alternating.
- Monitoring: TP focusing on one facet of the stimulus and:
    - Breathing group: one's own breath.
    - Sound group: a rhythmic background sound.

A repeated-measures ANOVA was performed on Duration Type X Task X Group on the time intervals produced (log2-transformed). A significant main effect of the task showed an increase in the durations produced by participants in Monitoring compared to Focused and Baseline (both $p<.001$). A significant Task X Group interaction showed that the durations produced in Monitoring in the Breathing group were significantly longer than in the Sound group ($p<.01$). Consistent with our hypothesis in the Breathing group, Monitoring significantly increased the time intervals produced compared to other tasks and that this was not true in the Sound group, where Monitoring had a similar attentional demand but no body component. This suggests that the division of attention between the TP task and the body led to longer temporal productions, highlighting the importance of inner awareness when considering meditation-like states and temporal perception.

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Variance of Temporal Context Influence Temporal Integration

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Abstract

Integration of information within temporal windows offers a way to explain how we perceive time-extended phenomena like motion, succession, melody etc. Here, we ask whether temporal integration windows are dynamically influenced by the ongoing temporal context. To study this, we developed a novel paradigm of temporal integration where two halves of a Kanizsa square are integrated together (seen as a full square) or segregated (not seen as a full square) as a function of temporal gap between them. We manipulated the inter-stimulus interval (ISI) between the two halves (30, 100, 300, 800ms). The two halves (T1 & T2) were preceded and succeeded by rotating discs of the same Kanizsa square in a temporally correlated (predictable) fashion. The rotation increments of the discs were randomly sampled from normal distribution with a mean of 25° with either a high standard deviation (SD) of 15° or a low SD of 5°. Additionally, we had two different trial types: 1) T-T where both T1 & T2 were present or 2) T-X where either T1 or T2 was presented, and the other frame was replaced with discs rotated by 180°. The SD conditions were presented in a ABAB blocked fashion. We asked participants (N=12) to report whether they perceived a full square or not within the sequence. Across 192 trials, we calculated the proportion of trials in which the square was seen correctly by the participant across all the conditions. We also calculated d′ and criterion scores across ISI and Condition for each participant. The proportion of trials in which an integrated square was seen decreased with increasing ISI. The main effect of Condition was not significant but the interaction between ISI and Condition was significant. The high SD among the rotation angles did not interfere with the ability to integrate the target stimuli overall. However, the proportion in low SD condition fell more steeply than in high SD condition with ISI. These effects were also present when the analysis was performed on d′ scores. The shallower slopes are usually interpreted as lengthening of the temporal integration window. Our study shows that the nature of temporal context systematically influences the extent of temporal integration windows.

SARS-CoV-2 During Pregnancy: Prematurity and Olfactory Response in Newborns

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Abstract

The SARS-CoV-2 virus pandemic caused olfactory loss in adults and children being one of the initial and most frequent clinical manifestations of the infection. Little is known about its effects on pregnancy, the puerperium and health of mothers and foetus. The goal of this observational comparative analytical cohort study of 96 new-borns up to 14 days old, 27% born prematurely, was to investigate olfactory perception in infants born from women who tested positive during pregnancy. Data collection was an experimental procedure exploring infants' responses to maternal breastmilk (essential), vanilla (sweet), coffee (acid/bitter) and distilled water (neutral).It was also possible to observe that the maternal infection period and gestational age, prematurity, had a negative impact on the duration of stimulus responses, especially for mouth movements, and the most significant response of the mouth angle.

The effects of COVID-19 (SARS-CoV-2) on maternal-fetal health are poorly understood, and the indirect impacts and neurological effects on the fetus remain inconclusive, although changes in maternal-fetal circulation have already been demonstrated due to the virus. The aim of this study was to investigate the response pattern of newborns to olfactory stimulation with breast milk in relation to the occurrence of prematurity and the incidence of SARS-CoV-2 during the gestational period.

The sample of this study was composed by 96 healthy neonates with age between 14 to 20 days of life, mean (standard deviation) gestational age of 38 (1.6) being 26 (27)% premature, Apgar 1st minute of 8 (1.3), Apgar 5th minute of 9 (.6); weight at birth of 3235.4g (.481), and maternal age of 30.7 years old (6.2). Written informed consents were provided by all of the participants' parents prior to participation or their tutors in case one or both parents had perished to the pandemic. The study was approved by the Research Ethics Committee from the University of Brasilia School of Medicine (http://www.fm.unb.br/cep-fm - CAAE 32359620.0.0000.5558) and was registered in the Brazilian Registry of Clinical Trials (ReBec) under number RBR-65qxs2. The sampling was for convenience over a period of 24 months and included all cases detected in periodic queries of data from the mandatory registration centre for positive results (National Directorate of Epidemiological Surveillance – Federal District-Brazil) and telephone contact was made with all women between 18 and 40 years old who tested positive for SARS-CoV-2. The sample size calculation could not be performed because there is no final data on the real prevalence rate of pregnant women infected with SARS-CoV-2 in Brazil.

Methodology encompassed the assessment of olfactory sensitivity based on four odors: coffee, breast milk, vanilla and distilled water, using specific criteria. Stimuli used in this study were chosen based on Bartocci et al (Bartocci et al., 2000). A systematic review on olfactory sensory and perceptual evaluation in newborn infants also indicated these odours as those more cited in infants' studies (Tristão et al., 2021). Odors were presented using cotton swabs for 30 seconds plus 30 seconds of baseline with 2-minute intervals between stimuli. The collection was recorded by video, and the Neonatal Behavioral Assessment Scale (NBAS) was applied after collection to evaluate infants' neural maturity. The data underwent correlation analysis and One-Way ANOVA using SPSS (Statistical Package for the Social Science) software. Shapiro-Wilk test was run for normality and the data was normally distributed.

Pearson's bivariate correlation analysis indicated a statistically significant correlation between clinical factors: gestational age, birth weight, APGAR and maternal age. The correlation with gestational age was negative for the babies' responses to Lips Puckering ($r = .588$, $p = .027$), Wrinkles Eyebrow ($r = .453$, $p = .020$) and Wide Eyes Opening ($r = .852$, $p = .007$), while it was positive for Lips Stretching and Gaping ($r = .995$, $p = .000$) and Crying ($r = .833$, $p = .039$). As for One-Way ANOVA, a significant difference was found between groups for Hand to Mouth Approaching Movements ($F = 116.833$, $p = .008$), with Gestational Age as a factor. Furthermore, a reduction in APGAR and gestational age was observed in newborns whose mothers were infected in the first trimester of pregnancy.

From these data, a relationship was demonstrated between prematurity and lower responses to breast milk, building an important relationship between the trimester of maternal infection, gestational age and response to olfactory stimulation. Hence, this study demonstrates important effects of maternal infection during the gestational period on maternal-fetal health, with statistically significant changes in several parameters, serving as a basis for future studies that evaluate the perinatal effects of SARS-CoV-2.

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Investigating the role of repetition suppression in Temporal Oddball Effect

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ABSTRACT

The oddball effect refers to the phenomenon where a novel stimulus (oddball) presented after repeated identical stimuli is perceived to last longer. A key explanation for this effect is repetition suppression, where repeated stimuli elicit reduced neural responses, leading to shorter perceived durations. Saurels et al. (2023) suggested that anticipation of the oddball stimulus may confound this effect and hence participants were informed of the fixed number of standards before the test stimulus, resulting in a positive linear relationship between the number of standards and the perceived duration of oddball events. However, their design removed uncertainty regarding the test stimulus, potentially diminishing attention to repeated stimuli and thus impeding repetition suppression. In our study, we manipulated the number of repeated stimuli, while we cued the test stimulus just before it appeared. Our results showed no perceived duration expansion for repeated stimuli but confirmed duration expansion for oddball stimuli. Additionally, we observed a linear increase in perceived duration for both oddball and repeat test stimuli as the number of preceding repeats increased, suggesting that the oddball effect is influenced by both repetition suppression and the number of repeated stimuli, up to a ceiling point.

Introduction

The oddball effect refers to a phenomenon in cognitive neuroscience and psychology where the perception of time is altered when individuals encounter a rare or unexpected stimulus (an "oddball") amidst a series of regular, expected stimuli. This effect has been attributed to attention engagement and its effect on the perceptual information processed (Tse, Intriligator, Rivest & Cavanagh, 2004). This effect has also been previously explained in terms of repetition suppression, a phenomenon where the neural response for repeated events is suppressed (Pariyadath & Eagleman, 2007; Grill-Spector et al., 2006).

One possible confound with the repetition suppression account of the oddball effect could be the increasing anticipation and hence attention engagement with each repeated event, resulting in longer perceived duration of the oddball stimuli (Saurels et al., 2023). According to Saurels et al. (2023), typical oddball paradigms confound the probability of oddball presentations with variable numbers of standard repetitions per trial. This confounding factor allows participants to increasingly anticipate an oddball presentation as more standards are presented. Saurels et al. (2023) eliminated this issue by informing participants of the fixed number of standards they would encounter before the final test input and by testing different numbers of standards in separate experimental sessions. In their study, the final event of sequences, the test event, was equally likely to be an oddball or another repeat. The results of this study showed a positive linear relationship between the number of preceding repeated standards and the perceived duration of oddball test events. However, this relationship was also observed for repeat test events, which contradicts the repetition suppression explanation of the temporal oddball effect.

However, we argue that Saurels et al., (2023) in their study only controlled for anticipation of target stimulus (oddball or repeat) but their way of controlling for target anticipation could have led the participants to not pay any attention to the preceding events just before the penultimate event. Hence the findings of their study may not be sufficient to explain the role of repetition suppression in the oddball effect.

In the present study we use a design similar to Saurels et al., (2023) with slight modifications ensuring the participants attend to each repeated event. Here we wanted to investigate if the participants pay attention to all the previous events and at the same time do not anticipate the target (oddball / repeat), would that again lead to similar effects as found by Saurels et al., (2023), specially would the expansion observed for repeated events observed in their study sustain if we control for attention to repeated events.

Methods

Participants

Based on the Saurels et al. study, we planned to collect data from 20 healthy participants with the age range 18-35 years. Here we present the data for a total of 10 participants (5 females, mean age = 24.9 years, S.D = 3.725 years).

Stimulus

The stimulus was presented on a 120 Hz refresh rate screen color monitor. Stimuli consisted of a sequence of white circles with a line tiled 45° towards either the left or right in an alternating fashion followed by either a white (repeat) or a black (oddball) at the end of the sequence. The circle's stimuli subtended 5.72° x 5.72°. The target stimulus is cued by a circle having a vertical line i.e. whenever they see a circle with vertical line, it would indicate the next event would be the target event (oddball or repeat). After the target display, a grey screen with a blue question mark (?) appeared where participants reported their response (see fig. 1). In each trial the participants reported if the duration of target was shorter or longer than the preceding repeated events.

All standard events appeared for 500ms and the duration of test events varied from 300-700ms with a step size of 50ms. The interstimulus duration (duration between two consecutive events) was 300ms. The length of the sequence varied from 3-10 (3, 4, 6, 8, 10) and appeared in random order ensuring that the participant does not know the exact length of the sequence but knows the exact location of the target event indicated by a cue. There was a total of 45 different trials (9 duration x 5 events). The experiment consisted of a total of 2 sessions of 6 repetitions (3 oddball and 3 repeat) of 45 trial types, resulting in a total of 270 trials in each session and 540 trials in the experiment. The participants had to pass the training test in order to start the main experiment which had a 80% accuracy criterion set to check if they can discern temporal differences in the target event.

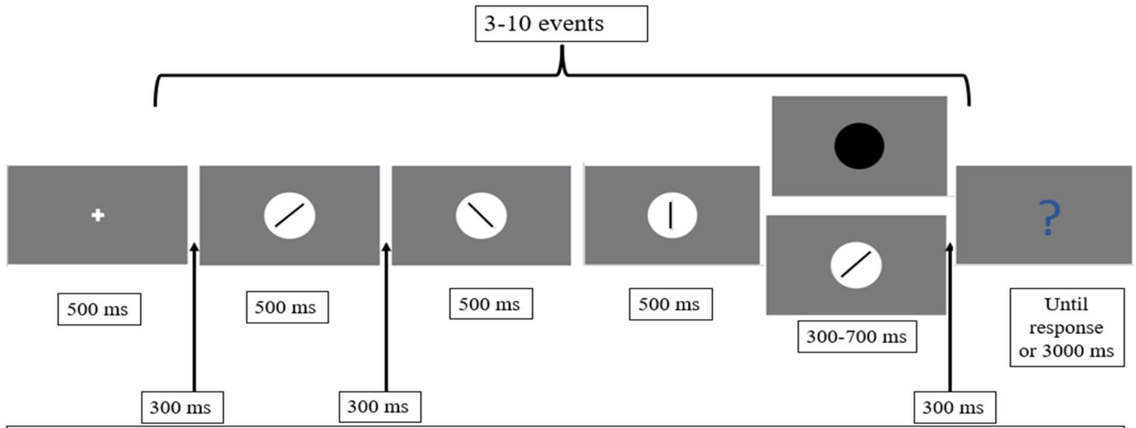

Fig 1. Illustrates the trial sequence from a 4 event trial. Each sequence starts with a fixation followed by white circles with lines oriented in an alternating fashion. The pre-target cue is indicated by a vertically oriented line. The participant has to report at the blue question mark by pressing 'L' if they felt the target was Longer and 'S' if shorter.

Results

DDF (Duration Distortion Factor) which is the ratio of Standard duration and Point of Subjective Simultaneity (PSE) is a measure of magnitude of expansion or contraction of perceived subjective duration. The DDF values are calculated by dividing PSE (Point of subjective equality) values by the duration of the standard event i.e. 500ms (e.g. for a standard duration of 500 ms and PSE of 400 ms results in DDF=1.25, suggesting a subjective expansion of the target duration). The PSE values were calculated using the python library 'psignifit' and further analyses were done using JASP (Version 0.19.0) .

The results showed that the DDF for oddball were greater than 1, and less than 1 for repeat events suggesting expansion of perceived duration for oddball target and contraction for repeat trials and this was consistent in all events. This finding is in line with the previous findings of Pariyadath and Eaglemen (2007) supporting the repetition suppression account of the oddball effect. Further the finding is in contradiction to Saurels et al. (2023) which showed a DDF > 1 for both oddball and repeat event.

No. of Events	t	df	p	VS-MPR
3	3.473	9	0.007	10.578
4	2.979	9	0.015	5.701
6	2.077	9	0.068	2.019
8	2.961	9	0.016	5.580
10	1.564	9	0.152	1.284

Table 1. Showing p values for paired sample t-test for event wise comparison between oddball trials and repeat trials.

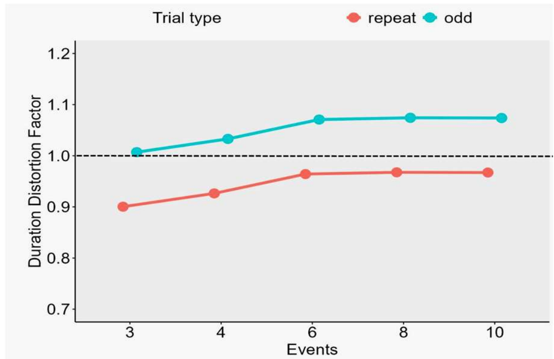

Fig 2. DDF values plotted against the number of preceding events. A DDF greater than 1 indicates subjective expansion.

We used a linear mixed model to examine the relationship between DDFs and the number of repeated events preceding oddball and repeat tests . The results showed a significant effect of Trial type (Oddball or Repeat), $F(1, 9) = 8.211$, $p = 0.019$ and main effect of event, $F(4, 12.56) = 4.731$, $p = 0.015$. However, the interaction effect was not significant. Further the mean DDF for oddball (M=1.052, SE = 0.029 is significantly higher than repeat (M= 0.945, SE= 0,037)

Discussion

Saurels et al.(2023) claim that the subjective expansion of oddball is due to increased anticipation and attentional focus with the presentation of each repeating event and not due to repetition suppression. However, one major issue with their design was that participants in their study knew exactly when an oddball would eventually appear. They did this by giving a countdown to the target on the preceding events. This could have possibly made participants pay less / no attention to the preceding events except the penultimate event. This could be the possible reason for not getting a DDF>1 FOR 2 event condition in Saurels et al. (2023), whereas for all other conditions, they found a DDF>1 for repeat events. In such a scenario the repetition suppression effect is less likely to show up as it requires the participants attend to each repeated event. In the present study we attempted to account for the role of repetition suppression in the oddball paradigm by removing anticipation of the target stimulus but still ensuring they attend to each repeated event. This allowed us to ensure that along with manipulating the number of preceding events and removing the anticipation for the target, the participants attended to each repeated stimulus in the trial.

In our design, the anticipation of the cue may have resulted in the overestimation of duration in the penultimate event. Assuming there is no role of repetition suppression in the oddball effect, anticipation and heightened attention of the cue should be influencing the perceived duration of oddball and repeat events similarly. Our results show a similar pattern as shown by Saurels et al (2023) but unlike their finding we found the DDF for repeat trials to be less than one and significantly shorter than oddball events. These findings can be better explained by the repetition suppression account.

Further, in our study, we observed a Ceiling effect of DDF between 6 and 8 events in both oddball and repeat trials. A similar trend has also been seen in Saurels et al. (2023), indicating that the effect of Repetition suppression is possibly limited to a certain no. of repeat events.

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Do You See an Object to Use It Or to Hold It: Role of Structural and Functional Actions in Object Processing

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Abstract

Actions associated with objects are tightly linked to their object concepts, a relationship demonstrated by facilitation of concept processing by action priming. However, not all actions have equal influence on processing of concepts, functional actions are thought to play a stronger role in concept processing, shown using a Stroop task (Bub et al., 2008) and priming in an object recognition task (Ni, Liu & Yeu, 2019) while structural actions provide little benefit for semantic access in a match-mismatch task (Bellis et al., 2016). Our aim was to investigate the relationship between structural actions and processing of object concepts. Fifty-two participants volunteered to participate in a match-mismatch task regarding either functional or volumetric properties of objects after they were primed either by structural or by functional actions matching one of the objects. We hypothesized that functional actions would have a stronger priming effect than structural actions. We demonstrate that both actions compared to a no prime condition provide some benefit in a categorization task related to a semantic property (functional similarity) and a volumetric property (size similarity) of objects; where that action knowledge is irrelevant. However, the results are non-conclusive about functional actions and interestingly, in contrast to previous work, we find a priming the effect size is greater for structural than for functional actions. Thus, the two types of actions, functional and structural, differ in terms of their strength of association to the objects and benefits of activation of actions is dependent on the kind of categorization task.

Introduction

Affordances are the possibilities of actions provided, invited, afforded by the environment around us (Gibson, 1979). Objects also afford several actions related to holding, grasping, and using them. One central debate has been regarding the importance of these action affordances in representation of the concepts related to these objects. Several studies have shown that viewing everyday objects invoke action representations associated with them (Myung, et. al, 2006) as well as viewing actions associated with an object facilitates subsequent naming of that object (Bub & Masson, 2006; Ni, Liu & Yeu, 2019), suggesting that actions associated with an object are an integral part of their concepts or at the least objects and the associated actions are strongly coupled in a bidirectional association.

Not all actions have equal influence on processing of these concepts, different types of actions seem to have differing levels of importance for the object concept. Researchers have distinguished between actions associated with objects into two classes - the Grasp system and the Use System, that differ in their processing (Buxbaum & Kalénine, 2010; Binkofski & Buxbaum, 2013). While the grasp system involves actions made to grasp and move an object (structural actions), the use system is concerned with actions made to use the object intended for its purpose (functional actions). These actions can at times be compatible with each other, while at other times be incompatible. For example, a calculator will have a 'clench' grip required to move it while a 'poke' action is required to use it; on the other hand, a glass will require the same clench grip to move and to use it. The objects with different actions for grasp and use are called action-conflict objects.

The Use system is said to represent actions related to long-term representations of objects while the Grasp system is an online system processing actions based on volumetric properties, orientation and such other information about currently visible objects (Buxbaum & Kalénine, 2010; Binkofski & Buxbaum, 2013). The two systems have other functional distinctions as well. The grasp system is activated early for shorter durations (Lee et al., 2012) and compulsorily (Jax and Buxbaum, 2010). On the other hand, the Use System takes time to be activated but it sustains longer, interferes with other semantic processing compared to grasp system in a concurrent semantic task (Creem and Proffitt, 2001), helps in early target identification among distractors in a Visual World Paradigm stimulus display (Lee et al., 2012; Ruotolo et al., 2019).

Previously, priming paradigm has been used to investigate action priming effects on object recognition (Helbig et al., 2006), where functional actions have exhibited strong priming effects, indicating their importance in object's concept, while the priming effect for structural actions is either absent or weak (Bub et al., 2008; Ni, Liu & Yeu, 2019). Interestingly, both type of actions have been demonstrated to be activated influencing object processing even in task-irrelevant situations (Bub et al., 2008). If as discussed earlier, the functional actions are more central to processing of object concepts then activating them should also activate other properties associated with the object. Priming participants with hand grasping an object (either functionally or structurally) influences object processing in a match/mismatch task but only for functional prime (Bellis et al., 2016), suggesting that structural actions or motor knowledge do not provide access to other semantic properties of the object.

However, such inference is incorrect due to the biased nature of task. The experimenters asked participants questions only about the functional match of the object. Another issue was the presence of object itself in the prime, making it difficult to dissociate repetition priming from action priming. These limitations leave unaddressed the question regarding structural action and the role they play in object processing. Thus, the purpose of this study is to investigate whether activating these two action systems – structural and functional; of an object concept, independent of the object, primes the object in question. We address these gaps by first, having a gesture only prime and second, by adding questions related to volumetric properties of the object. We also add a no-prime condition to provide a baseline comparison. If only the functional actions prime object representations, we should observe in congruence with earlier literature a priming effect only for functional primes, while structural primes should exhibit relatively lesser priming effect.

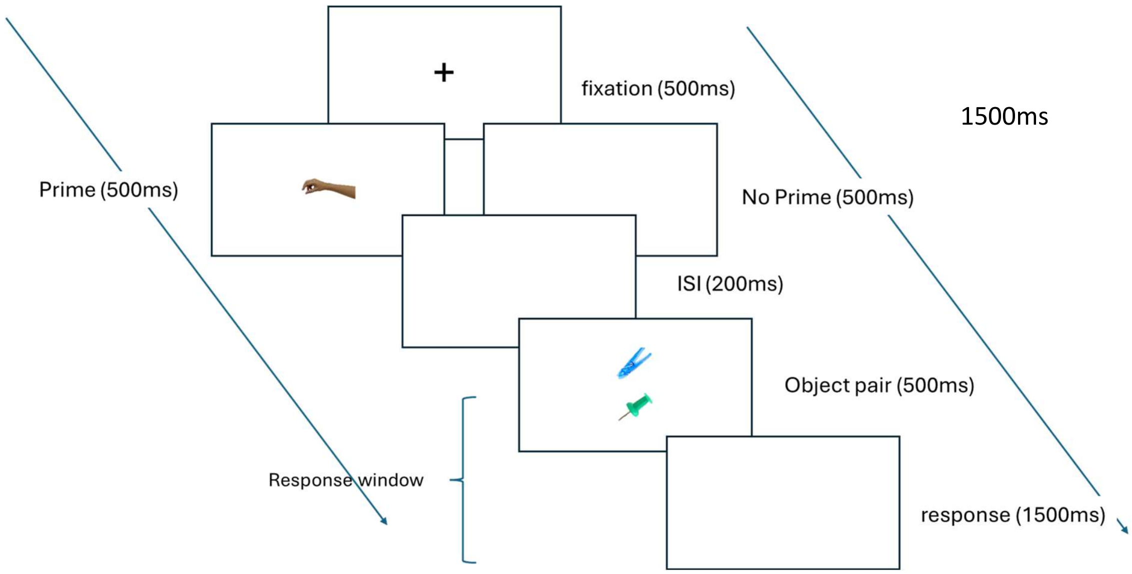


Fig.1. A trial example from structure block (the trial structure was same for both blocks).

Methods

Participants and Ethics Statement

There were two effects that we were interested in: priming effect for structure block and priming effect of function block. A pilot study conducted with 10 participants indicated an effect size: η_p^2 = 0.45 for structural and η_p^2 = 0.58 for functional block. The pilot study results suggested a sample size of 30 to obtain the smaller of the two effect sizes (half of the effect size for structure block, i.e., .225) with a power of 0.8 and alpha value fixed at .05 level. The sample size calculation was performed using More Power version 6.0.4 for main effect of priming in a 2x2 repeated measures ANOVA. The study was approved by the Institutional Ethics Committee.

52 students from IIT Kanpur (26 Males, mean age = 23.34 years, SD = 3.04) took part in the experiment in exchange for coupons worth Rs.100/- for a 40-minute session. All participants were right-handed, healthy and had normal or corrected-to-normal vision. Only right-handed participants were included because the orientation of objects (especially handled objects) can affect the action representations activated by the objects (Tucker & Ellis, 1998).

Stimuli & Apparatus:

The stimuli consisted of colored object pictures taken from image source - CIS - Chinese Image Set (Ni et al., 2018), open-source Canva, as well as photographed within the lab via iPhone 12 Mini, in controlled lighting. All the pictures of objects were then reset to a white background of 400 x 400 pixels. Objects with a long axis were oriented to either 90 degree or 45 degrees to maintain their grasp-ability. The stimuli were presented on a 24-inch BenQ Zowie XL LCD Intel® Gaming Monitor with display resolution set at 1920 by 1080 pixels at a refresh rate of 100Hz. The system used was HP Z2 Tower G5 Workstation with Intel® Core™ i9-10900 CPU running a 64-bit windows 11 Pro operating system. They were presented on a white background, standard mode, brightness 25; on top and bottom of the screen with a visual angle of 8.07°, approximately at a distance of 75cm.

Design and Procedure:

From a larger pool of items generated within the lab, objects having incompatible structural and functional actions, 8 object pairs matched in functional and 8 object pairs matched in size similarity pairs were selected. Functional similarity meant they served the same purpose/goal/function (e.g., lighter-matchbox), whereas size similarity meant that the 2 objects are of similar size in real life (e.g., football and basketball). To account for familiarity all objects were rated by 30 participants for familiarity in usage, handling and seeing on a slider between 0-100 with 100 indicating highly familiar. All objects with lower inter-rater reliability were removed from further analysis (two objects were removed). Within each pair, a reference object was selected, for which action primes, hand pictures were photographed in controlled lightning. They belonged to the same individual (female, 30) without any identification marks. These pictures were of an individual performing a hold (structural) action or a use (functional) action with respect to an object, without the object itself. These primes were presented at the center of the screen with a visual angle 10.08°, approximately at a distance of 75cm.

The experiment was created using PsychoPy version 2023.1.3. It was divided into 2 blocks – Function (primed with functional actions) and Structure Block (primed with structural actions). Within each block, there were 112 (56 Matched and 56 Mismatched) Prime trials and 112 No Prime trials, 224 trials per block. In both blocks, 8 Matched pairs were repeated 7 times (56 matched trials). In function block mismatched pairs were created pairing the 8 reference objects with the 7 other matches in other pairs. For structure block, 8 objects similar in structure but different in size (bigger or smaller) from the reference object in matched pair were selected beforehand; each such pair presented 7 times (56 mismatched trials). Here, different sized objects were resized to look similar in size.

Each trial began with a fixation cross (500ms), followed by a blank screen (no prime trial) or an action prime (prime trial) randomly selected, for 500msec, followed by 200 msec interstimulus interval with a blank screen. The target object pairs then appear, one on top, the other on bottom; for 500 msec and disappear. Participants are instructed to pay attention to the fixation cross, the hand gesture (if present) and respond when they see the target objects, beginning from when objects appear on the screen until the next fixation cross appears (1.5 s later from disappearance of target). In function block, participants were asked to respond if the pair displayed served the same function or not while in the structure block, participants were asked to respond if the pair displayed were similar in size in real life; while the pictures displayed are just a reference. The participants had to respond with keys ‘Z’ or ‘M’ for ‘YES’ or ‘NO’ on any given trial which was switched from participant to participant. To ensure that participants paid attention to the prime stimuli, 10 catch trials (per block) were included, in which the participants were presented with the objects from the previous trial and asked to pick the object they thought related to the hand gesture from previous trial.

Between 2 blocks, participants could take a break of 5-10 minutes. Before each block, participant completed a short practice session. The block order was counterbalanced across participants and the reference object in every pair was presented 50% of times on top and the other times on bottom. No same pair was repeated for at least 3 consecutive trials.

Thus, we manipulated action prime – function and structure and the object property to be judged. Within each block, we manipulate the priming factor – a prime or a no prime condition and, match factor objects matched or mismatched on an object property. Reaction Time and accuracy were the dependent variables measured. We expected reaction time of primed trials to be faster compared to not primed trials in both structure and function action priming blocks; given the background that action representations are tightly linked to their object concepts. We also expect that functional action priming effect size should be bigger than structure actions' priming effect.

Results

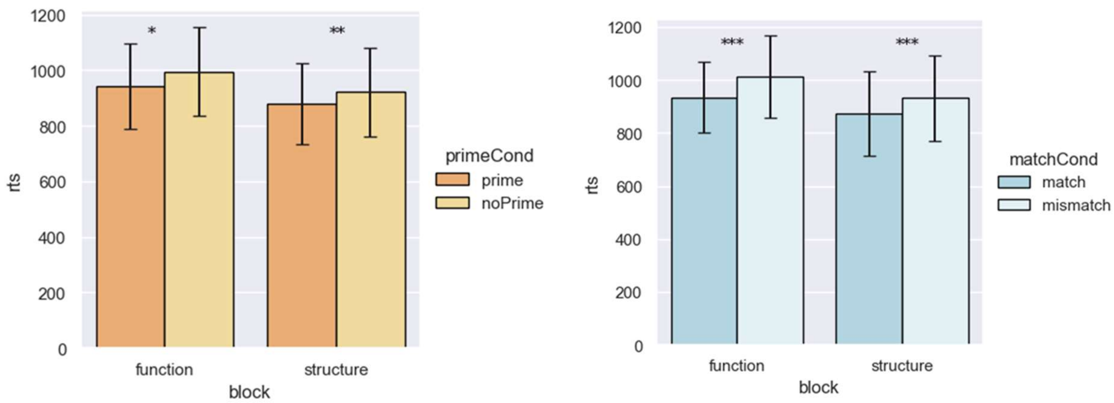
Data Filtering and Analysis:

The overall accuracy of participants was 80.21% (SD = 12.01); the accuracy in catch trials was 72.56% (SD = 15.01). First level of exclusions was in terms of accuracy; we removed those (twenty-two participants) with either poor performance in match/mismatch task (whose overall accuracy was below 65%) or individuals who did not notice the link between the prime and reference object (below 65% performance in catch trials). After exclusion, the overall accuracy was 93.17% (SD = 10.4), while the catch trial accuracy was 80.17% (SD = 8.71). As a second level of exclusion, we removed trials with reaction time beyond $\pm$ 3 Standard Deviation of mean RT for that participant (2.86% of total trials).

Next, we conducted two 2 (Match, Mismatch) x 2(Prime, No Prime) repeated measures ANOVAS for mean percentage accuracy as well as reaction time as a function of Prime condition and Match Condition, one for structure block and one for function block. We cannot combine these data points due to unbalanced design.

Accuracy:

For structure block, the analysis revealed no significant main effects of Prime Condition [F (1,29) = 4.159, p = 0.051, η_p^2 = 0.125], and Match Condition [F (1,29) = 0.323, p = 0.574, η_p^2



(a) (b)

Fig. 2. The barplots show Mean RTs in Prime Condition (A.) and Match Condition (B.) in both blocks. Error bars represent standard deviations (*$p<.05$*,**,$p<.01$,***$p<.001$).

= 0.01]. The interaction effect [F (1,29) =0.002, p=0.442, η_p^2= 0.020] was also not significant. For function block, the analysis revealed significant main effect of Prime Condition [F (1,29) = 7.404, p = 0.011, η_p^2 = 0.203], with participants being less accurate in Primed trials (mean = 85%, SD =13) than No Prime trials (mean = 90%, SD = 6). Main effect of Match Condition was not significant [F (1,29) = 2.012, p = 0.17, η_p^2 = 0.065]. The interaction effect [F (1,29) = 0.777, p = 0.385, η_p^2 = 0.026] was also not significant. Thus, the accuracy performance did not differ significantly across conditions, except in priming condition in function block.

Reaction Time:

In structure Block, the analysis revealed significant main effect of Prime Condition [F (1,29) = 8.971, p = 0.006, η_p^2 = 0.236] with participants being nearly 43ms faster in Primed trials (mean = 878.7ms, SD =160.3ms) than No Prime trials (mean = 921.25ms, SD = 159.38ms). Main effect of Match Condition was also significant [F (1,29) = 20.272, p < 0.001, η_p^2 = 0.411], matched trials were approximately 59ms faster (mean = 872.39ms, SD = 155.39ms) than Mismatched trials (mean = 931.71ms, SD = 160.57ms). The interaction effect [F (1,29) = 0.035, p = 0.854, η_p^2 = 0.001] was not significant.

In function block, the analysis revealed significant main effect of Prime Condition [F (1,29) = 7.424, p = 0.011, η_p^2 = 0.204] with participants performing nearly 53ms faster in Primed trials (mean = 942.92ms, SD = 155.06ms) than No Prime trials (mean = 995.44ms, SD = 145.57ms). Main effect of Match Condition was also significant [F (1,29) = 42.687, p < 0.001, η_p^2 = 0.595] with Matched trials being nearly 79ms faster (mean = 934.1ms, SD =

133.2ms) than Mismatched trials (mean = 1013.44ms, SD = 159.05ms). The interaction effect [F (1,29) = 0.619, p = 0.438, η_p^2 = 0.021] was not significant.

Discussion

Both the action primes, structural and functional actions show a priming effect, influencing object processing, aiding in the subsequent object categorization task as can be seen in Figure 2. Importantly, action-related knowledge is irrelevant to the categorization task at hand. Consistent with previous literature, we find that both actions are linked to object concepts (Bub et al., 2008). However, we see that people are faster yet less accurate when primed by functional actions. Thus, functional action priming results are inconclusive. The notion that only functional actions or the Use system is related to long-term representations of objects, or dominant to object concepts is challenged by the evidence we find in this experiment. The effect size for structural action priming is also more than functional action priming.

Thus, the Grasp and Use system, both seem to be tightly linked to their object concepts, aiding in its concept retrieval faster and helping in judging semantic or volumetric property of objects. Interestingly, the Grasp System seems to be more influential in object processing than the Use System. This can be explained as structural actions being linked to volumetric property of objects more strongly; an object property like size would be necessary to guide reaching-grasping actions (Caprara et al., 2018). Thus, there seems to be a difference in how and when the two actions contribute to object processing, that is, their magnitude of influence seems to be dependent on context and task (Kalénine et al., 2014); namely, the object property to be accessed in the current categorization task. The priming effects of structural actions seem consistent with the notion of stable affordances (Borghi & Riggio, 2015), where the typicality of grasp action is dependent upon the typicality of the object size; size is considered an intrinsic property to objects. Thus, the grasp actions are tightly anchored with the volumetric properties of objects. Both actions seem to be integral to object concept processing, but when one is more influential depends on the context.

We speculate this is contingent upon the differential processing in the 2 action routes proposed for the two action systems, Dorso-Dorsal for Grasp system and Ventro-Dorsal for the Use system (Buxbaum & Kalénine, 2010). Proposals about intermediate object representation in dorsal stream suggest that color, form, and other object related information from ventral stream is integrated into dorsal stream which contributes to the decision-making process and subsequent actions undertaken (Perry & Fallah, 2014).

It is important to investigate the priming effects in comparison to an incongruent prime or a neutral prime condition, to identify whether a priming effect truly exists especially in the functional actions case and also dissociate the benefit provided by priming in absence of any prime versus an invalid or non-beneficial information. An interesting question to explore is whether these effects would still hold in light of switching the action systems and asking the opposite question – functional action priming and performance on a judgement task about volumetric property of objects, and structural action priming and its performance on a semantic judgement task about objects; how far the influence would hold. Thus, more studies need to be conducted in different task contexts to identify and separate out the differential role played by these two action systems in concept processing of objects.

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Visual Global and Local Processing in the Broader Autism Phenotype Depends on the Stimulus Material

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Abstract

The way we visually perceive the global structures and their local parts in our environment has been shown to vary from person to person in relation to individual differences such as autistic-like traits. Superior performance on the Embedded Figures Test (EFT), a measure of local processing preference, has previously been linked to higher levels of social, but not non-social, autistic-like traits. To further explore this relationship, we employed the EFT along with two modified versions of the Navon task, which used numerical and geometrical compound hierarchical stimuli. Our investigation focused on visual global and local processing in neurotypical adults in relation to their autistic-like traits. In accordance with previous findings, we replicated a positive correlation between autistic-like traits and faster reaction times for the EFT. While not reaching significance, the direction of this relationship was mirrored for the geometrical Navon task. However, for the numerical Navon task, findings were unexpected: Increased autistic-like traits were associated with a greater global bias in reaction times. Aligning with previous findings, significant relationships were only found for the social but not the non-social autistic-like traits. However, our findings suggest that these vast between-task differences in relation to visual local and global processing are related to stimulus material and need to be taken into consideration in future studies.

Visual processing refers to the brain's ability to interpret visual information from the eyes, a complex process involving the reception, analysis, and interpretation of visual stimuli. This process extends beyond simply adding up visual inputs, as the global whole is distinct from the sum of its local parts, a key principle of Gestalt psychology (Wagemans et al., 2012). Despite this universal principle, significant individual variations exist, with some individuals displaying a local bias and others a global bias (Chamberlin et al., 2017). These inter-individual differences have been linked to various traits such as autistic-like traits. This link has frequently been investigated using the Embedded Figures Test (EFT; Witkin, 1950) which measures local visual processing preference. The goal of our study was to investigate whether findings can be generalized to another experimental task which measures both local *and* global visual processing preference using different stimulus material.

The EFT requires participants to locate a simple target shape within a complex line pattern. When the target shape is integrated into the surrounding context, it becomes challenging to identify, as it is perceived as part of a global whole. As a result, the line pattern overwhelms perception, causing the target shape to be "embedded" within the context. Thus, the task is assumed to investigate the ability to see a local item independent of the global context in which it is embedded (Witkin et al., 1971). A newer computerized version, the Leuven Embedded Figures Test (L-EFT; de-Wit et al., 2017) facilitates measuring reaction time (RT) and accuracy of responses. Faster RTs indicate a stronger local processing preference.

Superior performance on the (L-)EFT has been observed in autistic individuals, with faster but equally accurate responses (Jolliffe and Baron-Cohen, 1997), suggesting enhanced perceptual discrimination abilities (Plaisted, 2001). This relationship extends to neurotypical individuals, where higher autistic-like traits correlate with better (L-)EFT performance (Almeida et al., 2010), supporting the idea of a broader autism phenotype in which autistic-like traits are continuously distributed across the general population (Ruzich et al., 2015). These traits are often measured using the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2006). On this scale, a higher AQ score indicates a greater prominence of autistic-like traits. In line with the idea that autistic traits form largely independent domains, analyses of the AQ factor structure have consistently reported two domains; one related to social and one related to non-social anomalies (Austin, 2005). Research has shown that superior (L-)EFT performance is linked specifically to higher scores on the social AQ factor (Russell-Smith et al., 2012). This finding suggests that the relationship between local processing preference and autistic-like traits is linked specifically to the social rather than non-social traits.

However, the (L-)EFT only measures local visual processing preference. The weak central coherence (WCC) theory posits that this preference could result from either a global processing deficit or a local processing strength (Happé & Frith, 2006). To explore both local *and* global visual processing preference, another traditional task can be used presenting compounded-figure stimuli (hierarchical figures). This paradigm consists of presenting the participant with an image of one large figure (global level information) composed of suitable arrangements of multiple small figures (local level information; Navon, 1977). The task consists of attending to either the global or local level to indicate the figure displayed at the respective level. In the current study, hierarchical figures consist of geometrical shapes for the Geometrical Navon Test (GNT; like in, e.g., Beaucousin et al., 2011). A modified version, the Compound Figure Test (CFT; Lacko et al., 2020), uses numerical figures.

Our study aims to generalize the relationship between social autistic-like traits and local processing preference from the (L-)EFT to other tasks like the Navon paradigm, which examines both local and global processing preferences. We recruited native German speakers to minimize cross-cultural variations (Lacko et al., 2020). We quantified their autistic-like traits using the German short version of the AQ (AQ-K; Freitag et al., 2007), which identifies three factors encompassing the two domains: social (Social Interaction/Spontaneity, SIS) and non-social (Fantasy and Imagination, FI; Communication/Reciprocity, CR) domain. We investigated the relationships between these factors and visual processing preferences across the three tasks, differing in design (L-EFT vs. Navon tasks) and stimulus material (shapes vs. numbers).

Method

Participants & Cognitive Assessments

We recruited 105 native German speakers (41 female, 64 male) between 19 and 35 years of age (M = 24.91, SD = 3.15) from the University of Kaiserslautern-Landau. All participants had normal or corrected-to-normal vision and were compensated with course credits. Autistic-like traits were quantified using the AQ-K's 33 self-descriptive items scored on a four-point scale (Austin, 2005), assessing the factors SIS, FI, and CR. Higher scores indicate greater social (SIS), imagination (FI), or communication difficulties (CR). Participants completed the AQ-K after the experimental tasks. Four additional cognitive assessments were filled out but are not included in this paper.

Experimental Measures

After providing written consent, participants were seated in front of a laptop in a sound-attenuated room with controlled lighting. All tasks were presented in black on a white background using PsychoPy. First, participants completed the GNT (similar to Beaucousin et al., 2011), a modified version of the Navon task using geometrical hierarchical figures (circle, hexagon, square, star). The stimuli were either congruent (same global-local shapes) or incongruent (different global-local shapes). Participants identified either the global or the local shape by pressing the corresponding keyboard button (images of the shapes were attached to the buttons). The GNT consisted of 320 trials presented in a counterbalanced design (one global and one local block). Each trial began with a fixation cross presented for 500 ms, followed by a geometrical figure displayed until the participant responded. The task included 32 practice trials (16 global, 16 local) with visual feedback (correct/incorrect) for 1000 ms.

The second task was the CFT (like in Lacko et al., 2020), another modified version of the Navon task using numerical hierarchical figures (2, 4, 5, 8). The experimental design mirrored the GNT, except for the stimuli and the number of trials. Participants identified either the global or the local number by pressing the corresponding keyboard button (2, 4, 5, or 8). The CFT consisted of 6 practice trials (3 global, 3 local) with feedback and 32 experimental trials in a counterbalanced design (one global and one local block) with the same timing as the GNT. Stimulus congruency was randomized for both GNT and CFT. Performance was measured by average RT and accuracy in locating the global and local stimuli.

The third task, the L-EFT (de-Wit et al., 2017), required participants to identify a target shape within a complex figure. The task included 16 target shapes embedded in four contexts with increasing complexity. In each of the 64 randomized trials, one target shape and three context figures (one containing the target, two distractors) were displayed until a response was made. Performance was measured by average RTs and accuracy in locating the target shape, using keyboard buttons (1 for left, 2 for center, or 3 for right).

Statistical Analysis

For each of the three tasks, the first trial in each block was omitted to account for warm-up effects. Trials with RTs faster than 200 ms or slower than 2 s for the two Navon tasks (CFT: 1.11%; GNT: 0.92%) and 180 s for the L-EFT (0%) were removed. Mean RT was calculated using correct trials, and trials with RTs more than 3 standard deviations from the participant's mean in each condition were excluded, removing 1.6% for the L-EFT and 1.46% for the GNT on average. No outliers were identified for the CFT. The participants scoring below or near chance in a condition ($N_{CFT} = 2$; $N_{GNT} = 6$) were excluded from further analysis.

To assess the relationship between the L-EFT performance and the autism traits, Pearson's correlation coefficients were calculated between the behavioral values (mean RT and accuracy) and the AQ-K factors (SIS, FI, & CR) in R with RStudio. For the Navon tasks, the *global bias* (Local minus Global; a higher global bias indicates a bias towards faster global than local processing) and the *global interference* ([$\text{Local}_{\text{Incongruent}}$ minus $\text{Local}_{\text{Congruent}}$] – [$\text{Global}_{\text{Incongruent}}$ minus $\text{Global}_{\text{Congruent}}$]; a higher global interference indicates a larger disruptive influence from conflicting irrelevant global information in incongruent trials on local identification than local conflicting information in incongruent trials on global identification) were calculated for RT and accuracy (de Fockert & Cooper, 2014). Pearson's correlation coefficients were then calculated between these behavioral measures (global bias & global interference) and the AQ factors. Graphics were created using ggplot2.

Results

The participants' mean scores across all items of the AQ-K varied between 0 and 25 ($M = 9.73$; $SD = 6.25$). This broad distribution of autistic-like traits across our neurotypical sample is in accordance with the idea of a broader autism phenotype (Ruzich et al., 2015). The distribution of individual levels of autistic-like traits varied similarly on the three factors SIS ($M = 2.74$, $SD = 2.96$), FI ($M = 3.55$, $SD = 2.39$), and CR ($M = 3.44$, $SD = 2.14$).

For accuracy, no relation to the autistic-like traits was observed for any of the three experimental tasks (all *p*s > 0.05). For RTs, we observed in the L-EFT a significant negative correlation between autistic-like traits for the SIS factor ($r(105) = -.25$, $p = .009$; Fig. 1) but not for the FI or the CR factors (*p*s > .74). Thus, more social interaction and spontaneity difficulties were associated with faster RTs. In the CFT, there was a significant positive correlation between autistic-like traits and global processing bias for the SIS factor ($r(103) = .25$, $p = .012$; Fig. 1) but not for the FI or the CR factor (*p*s > .077). Thus, more social interaction and spontaneity difficulties were associated with more global bias in the RTs. In the GNT, although associations were in the same direction as for the L-EFT (less global bias for higher SIS; Fig. 1), none of the correlations with AQ-K factors (SIS, FI, & CR) reached significance (all *p*s > .11). For both the CFT and the GNT, no relation between the global interference and the autistic-like traits was observed (*p*s > .06).

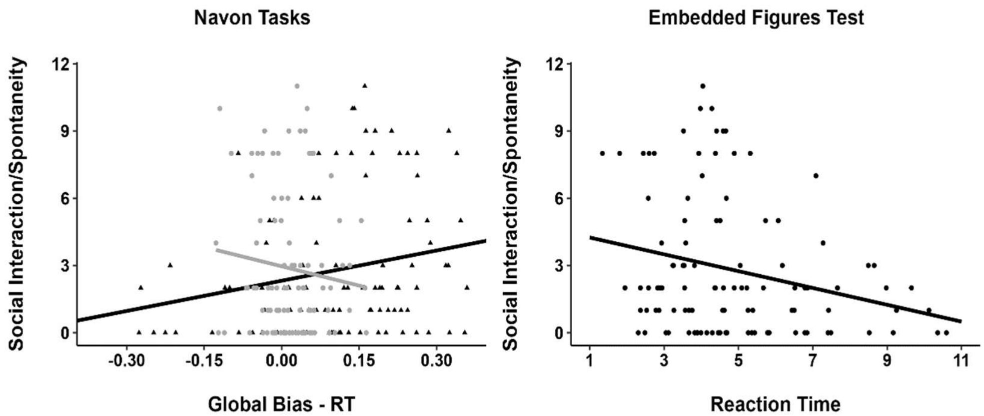

Fig. 1. Relation between L-EFT RTs (in s) and Navon tasks (CFT in black and GNT in grey) global bias (in s) and SIS.

Discussion

Our study aimed to generalize the relationship between social autistic-like traits and local processing preference, observed in the (L-)EFT, to other tasks like the Navon paradigm. Findings for the L-EFT were in line with previous studies (Jolliffe and Baron-Cohen, 1997) as evidenced by superior performance (i.e., faster RTs) correlating with higher levels of autistic-like traits. In line with Russel-Smith et al. (2012) this association was only found for the social (SIS) but not the non-social AQ-K factors (FI & CR). This replicates the general idea that autistic-like traits are frequently associated with a local visual processing preference. However, the WCC theory posits that this preference could result from either a global processing deficit or a local processing strength (Happé & Frith, 2006).

To investigate this relationship separately for local compared to global visual processing, participants also completed two versions of a Navon task (GNT & CFT). Correlating the global bias with autistic-like traits for the GNT, we found that although following the same direction as in the L-EFT (less global bias for higher levels of autistic-like traits), these correlations did not reach significance. For the CFT, social autistic-like traits significantly correlated with global bias whereas no association was found for the non-social factors (FI & CR). However, the direction of this correlation was in opposition to the relationships of both L-EFT and (although insignificantly) the GNT: Higher levels of autistic-like traits related to a greater global bias.

The between-task differences in the direction of the relationship with autistic-like traits might be due to the stimulus material, using numerical stimuli in the CFT and geometrical shapes in the L-EFT and GNT. Following the discussion by Lachmann et al. (2014), the visual processing of culturally meaningful symbols (such as numbers) differs significantly from the visual processing of culturally less meaningful symbols (such as geometrical shapes). Autistic traits related to culturally meaningful processes, such as language, have further been associated with differences in brain activity (Plueckebaum et al., 2023). Another precursor affecting the between-task differences in findings might be the difference in stimulus size across the two Navon tasks: The compound figures of the GNT were composed of one large geometrical shape made of 20 smaller shapes, whereas the compound figures of the CFT were composed of more than 100 smaller numbers. Therefore, while the global figures are the same size across both tasks and in line with recommendations by Ventura et al. (2021; approximately 5° visual angle), the size of the local figures is only in line with these recommendations for the GNT (local shapes not smaller than 0.3° visual angle) but not the CFT. These stimuli-related differences might have affected the results and further studies are needed to clarify how these differences can explain the opposite findings for L-EFT and GNT as compared to the CFT.

In conclusion, our findings replicate the relationship between social autistic-like traits and local processing preference from the (L-)EFT. The generalization of this relationship to the Navon paradigm was observed to depend largely on the stimulus material, in terms of size and meaningfulness of the figures. Future studies should explore this relationship further to deepen our understanding of visual processing in the broader autism phenotype.

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