# FIRST IMPRESSIONS BIAS SOUND SEQUENCE LEARNING ON MULTIPLE TIMESCALES:

# AN ORDER-DRIVEN PHENOMENON IN AUDITORY MISMATCH NEGATIVITY


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# Abstract

Humans are prone to systematic biases in perception that impact rationality in judgement. First impression bias occurs when judgement is overly affected by information presented during an initial encounter. Using the amplitude of a specific brain response, the mismatch negativity (MMN), our team discovered that the brain is prone to this bias effect during the very early stages of sound sequence learning preceding knowing awareness. The aim of this thesis was to determine which experimental conditions expose or modify first impression bias effects on sound pattern learning on multiple timescales. Predictive coding models assume the brain is hierarchically-organised and uses perception to make inferences about the sensory world whilst updating predictions about incoming sensory information. Recurring comparisons between bottom-up input and top-down predictions consider environmental noise, and determine the inferential modelling process. MMN, an event-related response evoked by violating regularity in a structured sound sequence, is an example of a prediction error signal. Its presence informs on prediction model content whereas its amplitude informs on model confidence (or precision). Prediction error amplitude to a pattern violation is largest when model confidence is very high and may require engagement of additional, higher-order resources. First impression bias shows that the network uses contextual information at sound sequence onset to modulate MMN amplitude to probabilistic changes thereafter. This thesis shows that first impression bias is a remarkably robust and long-lasting phenomenon that can be interrupted if participants undertake an attention demanding task whilst hearing multi-timescale sequences or are provided with accurate foreknowledge about sound structures before sequence exposure. This thesis discusses how models assuming only local sound probabilistic information drives the MMN-generating process cannot explain bias effects on MMN amplitude. Rather, the bias is a striking example of a hierarchical inference process incorporating attentional resources that considers the potential relevance of sound information and its stability over time.

# Statement of Originality

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision.

The thesis contains published scholarly work of which I am a co-author. For each such work a written statement, endorsed by the other authors, attesting to my contribution to the joint work has been included.

The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo

SIGNED:

Jade D. Frost

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# Table of Contents

# List of Figures

**Chapter 1: Background and Rationale**



**Chapter 2: Surprising Sequential Effects on MMN**



**Chapter 3: Increased demand on cognitive resources abolishes effects of first impression bias on sound sequence learning**



**Chapter 4: Foreknowledge about the auditory environment abolishes first impression learning bias**

# List of Appendices

# Acknowledgement of Authorship

I attest that Research Higher Degree candidate Jade D. Frost has contributed to publications for which I am a co-author. For all publications, where applicable, Jade has:

- Contributed to the development of research questions
- Contributed to research design and methodology
- Managed data collection procedures
- Oversaw experimental implementation
- Processed the data
- Led data analysis
- Led writing of the manuscript

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# Abbreviations

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ART | Adaptive Resonance Theory |
| DCM | Dynamic Causal Modelling |
| DVD | Digital Versatile Disc |
| EEG | Electroencephalography |
| ERP | Event-Related Potential |
| EOG | Electro-Oculograms |
| HGF | Hierarchical Gaussian Filtering |
| ISI | Inter-stimulus interval |
| MMN | Mismatch Negativity |
| MRI | Magnetic Resonance Imaging |
| PAC | Primary Auditory cortex/cortices |
| PFC | Prefrontal Cortex |
| PT | Perceptual Task |
| SOA | Stimulus Onset Asynchrony |
| SSA | Stimulus Specific Adaptation |
| WM | Working Memory |

# Synopsis

Our team has discovered that the brain is susceptible to *first impression bias* effects during very early processing of information in sound pattern learning across time. Evidence of bias shows that the order in which sound information is heard markedly changes how pattern learning proceeds, a phenomenon comparable to primacy effects observed in psychological studies (e.g. Asch, 1946; Bargh & Pietromonaco, 1982; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Devine, 1989; Hamilton, 1979; Nisbett & Ross, 1980; Perdue & Gurtman, 1990; Pratto & Bargh, 1991; Rothbart & Park, 1986; Rozin & Royzman, 2001; Skowronski & Carlston, 1992; Wyer, 1973). In this thesis, we[1] apply a widely known neuroscientific psychophysiological technique, electroencephalography (EEG), and use sequences comprising patterns that emerge over multiple timescales to further expose under what conditions first impression effects are observed or are modified. We use a brain response called the mismatch negativity (MMN), a component of the auditory event-related potential (ERP) that is evoked automatically when some aspect of the sound environment unexpectedly changes. The MMN is described in the literature as a measure informing about neural states underlying central auditory processing at the cortical level. More specifically, it can be used to study the brain's capacity to 1) learn transitions statistics underlying sound patterning that emerge in environment as time unfolds, and 2) use this information to anticipate the next most likely state of neural activation.

In a series of studies, we have shown that MMN amplitude to transitional probabilities over the shorter term is modulated by contextual learning in a way that

[1] Whilst I understand it is conventional to use “I” in a thesis, I prefer to use "we" to reflect the joint venture I experienced during my candidature.

cannot be accounted for by prominent models proposed in the MMN literature. Hence, we propose that the brain utilises hierarchically-organised inference mechanisms that are sensitive to transition statistics at multiple timescales and include sophisticated means for estimating the relevance of one sound event over another. Further, we think that the susceptibility of relevance filtering mechanisms to first impression bias occurs because estimates based on initial experience of one context (in which transition statistics are heard) has undue influence on estimating sound relevance based on probabilistic information later. This interpretation is consistent with assumptions put forward by predictive coding accounts of learning and accordingly, research questions in this thesis are formulated using theoretical principals described under this framework. In all experiments, we use variants of a sound sequence called the multi-timescale paradigm that contains transition statistics that emerge over both the shorter and longer term. The work described here is guided by a focus on specific experimental manipulations that are formulated in terms of hypotheses informing on potential mechanisms underlying first impression bias effects in auditory relevance filtering.

This thesis is organised as follows:

**Chapter 1: Background and Rationale**

The MMN literature is reviewed and predictive coding theory from which research questions in the present thesis are formulated is also described. In the latter half, our research findings generated by studying the first-impression bias in early relevance filtering under different conditions will be explained; the rationale for extending this knowledge in the present thesis will also be put forward.

**Chapter 2-4: Results chapters**

The experimental work including the aims, hypotheses, methods and the outcomes for each study are described. In each experiment, variants of the multi-timescale experimental paradigm are used to test research questions generated about first impression bias modulatory effects on MMN amplitude. The specific goals of each study were as follows:

- To replicate patterns of first impression bias effects using a much larger sample size relative to those included in previously published studies (Chapter 2)
- To determine the effect of first impression bias on sound pattern learning following repeated exposure to more stable or more volatile sound sequences (Chapter 2)
- To determine if learned patterns of first impression bias effects remain if participants are engaged in a concurrent task that places high demands on attentional and/or working memory resources whilst hearing the multi-timescale paradigm (Chapter 3)
- To determine if knowledge about local and context-based sound structures before hearing the multi-timescale sequence affects first impression bias effects on sound sequence learning (Chapter 4)

**Chapter 5: General Discussion and Conclusions**

A general discussion and the conclusions of this work including contributions to the research field and possible directions for future research are provided.