Distinguishing High and Low Flow States During Video Game Play Through the Mismatch Negativity to Task-Irrelevant Sounds

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BACKGROUND

Flow state

Often described as *"being in the zone"*, flow has been studied across a wide range of activities for over 50 years[1,2]. Characteristics include

- Fully focused attention
- Optimal Performance
- Transformation of time
- Autotelic experience

Studies of the neural bases of flow typically document differences between a state of **flow** - during which challenge is balanced with skills - and one of **boredom**, where the task is too easy, confounding flow with being **on-task versus off-task.** As a result, its neural bases remain poorly understood.

Present ERP study of flow induced through video game play

In addition, auditory oddball sequence **passively** presented, as in previous work characterizing the neural fate of task-irrelevant stimuli during flow[3].

We focus on three auditory ERP components:

- **N1** (early sensory response),
- **Mismatch Negativity (MMN)** (automatic change detection)
- **P3a** (attentional orienting response)

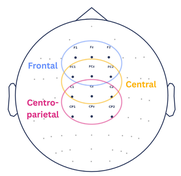
Predictions

Dominant theories of flow (Hypofrontality[4], Attention-Reward Synchrony[5], and others) predict that irrelevant sounds will receive fewer processing resources, with reduced N1, MMN, P3a during high flow, as when people in flow report being unaware of their surroundings.

Are task-irrelevant auditory ERPs reduced during high vs. low flow?

METHODS





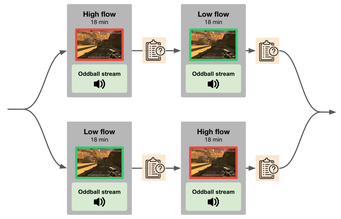
Flow induction

States of high and low flow induced by titrating a first-person shooter video game (Unreal Tournament 2004) to each participant's skill level[6].

High flow : challenge-skill balance

Low flow : slightly too hard, yet on-task

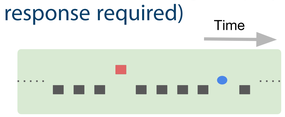
A best-try subscale (IMI)[7] confirmed comparable task interest across conditions.



Flow order counterbalanced across participants

Passive auditory oddball

Sounds presented during gameplay (no response required)



Standard	800 per block (80%) · 750 Hz
Deviant	100 per block (10%) · 1500 Hz
Novel	100 per block (10%) · environmental sounds

EEG acquisition & processing

64-channel EEG · **Independent annotation** of bad channels and segments · **ICA** with large decomposition, mastoids cleaned separately, component rejection by **independent raters**

Flow selection (FSS-2)[8]

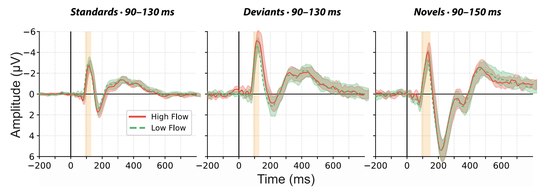
High flow > **low flow** in N=41 participants

t(40) = 11.97, p < .001, d = 1.87

Participants with levels in the wrong direction were excluded

RESULTS N=41

N1 - Standard, Deviant, Novel; *no flow effect, but confirms data quality*

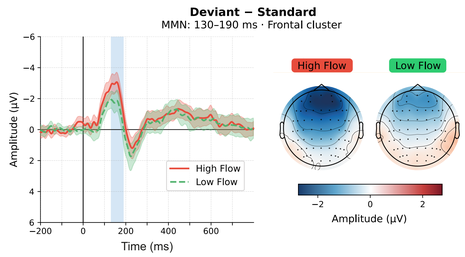


N1 is a well-established marker of early auditory processing, sensitive to physical stimulus parameters and attentional state

Clean, well-defined N1 to all sound types, despite the noisy gaming environment, confirming reliable ERPs can be extracted.

MMN deviant - standard larger in high flow

t(40) = -2.81, p = .008, d = -0.44



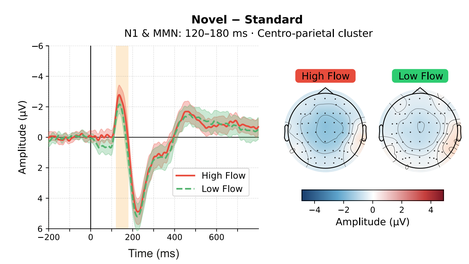
MMN reflects preattentive automatic change detection, long considered independent of attention[9]. Our group[10] concluded that the MMN was in fact affected by attention under certain circumstances

Contrary to predictions, MMN was larger during high flow, suggesting heightened rather than reduced early auditory processing

Larger MMN reflects enhanced detection of sound change between the "standard" memory trace and the incoming deviant sound

MMN novel - standard larger in high flow

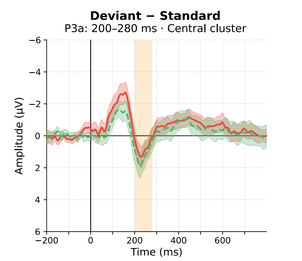
t(40) = -2.45, p = .019, d = -0.38



A larger MMN was also elicited by complex novel sounds in high flow, suggesting stronger memory traces and thus greater sensitivity to deviance

Typically, larger MMN is followed by a larger P3a, does the flow effect on MMN follow this pattern?

P3a: deviant - standard *n.s.*

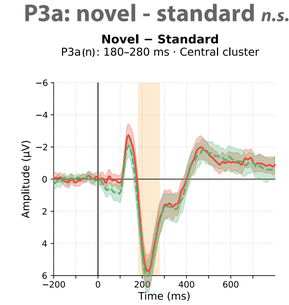


P3a is the bottom-up orienting response that typically follows MMN

Contrary to what is typically expected from a larger MMN, there was no corresponding P3a difference

Thus, in the case of flow, the MMN enhancement is not followed by attentional reorientation

P3a: novel - standard *n.s.*



The P3a to novel sounds was similarly not affected by flow state

CONCLUSIONS

High flow -> larger MMN (deviant & novel)

Main results

- MMN larger in high flow, for both simple frequency deviants and more complex novel sounds
- P3a unaffected in both contrasts

Interpretation

Contrary to the dominant view, task-irrelevant processing was not dampened during high flow. MMN was larger, suggesting early auditory processing may have been heightened rather than suppressed.

This MMN/P3a dissociation suggests flow sharpens early **auditory sensory memory** while not being accompanied by **attention reorientation**.

Ignoring meaningful sounds while deeply engaged may reflect **later selection**, not early gating.

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