Flow as optimal user state for immersion and performance in BCI

Jelena Mladenovic
Inria Bordeaux, France
Lyon Neuroscience Research Center, France
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Thorndike

Skinner
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1938)

Thorndike

Skinner

The elements of psychology 1905
The Behavior of Organism: An Experimental Analysis (1938)
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1938)

The elements of psychology 1905
The Behavior of Organism: An Experimental Analysis (1938)

in BCI

Wolpaw et al. 1991 “An EEG-based brain-computer interface for cursor control” Electroencephalography and clinical neurophysiology

Pfurtscheller et al. 1993 Brain-Computer Interface—a new communication device for handicapped persons, journal of microcomputer application.
Why standard brain-computer interface (BCI) training protocols should be changed: an experimental study.
Jeunet, Jahanpour and Lotte, 2016
54 subjects
17% failed

Why standard brain-computer interface (BCI) training protocols should be changed: an experimental study.
Jeunet, Jahanpour and Lotte, 2016
Feedback for learning

Behavioral Theories:
- Law of effect (Thorndike, 1905)
- Operant Conditioning and Reinforced Learning (Skinner, 1948)

Extrinsic motivation

Cognitive Developmental Theories:
Intrinsic motivation
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1948)

Cognitive Developmental Theories:
Intrinsic motivation

Zone of Proximal Development
(Vygotsky, 1930)

Mind in society: The development of higher psychological processes.
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1948)

Cognitive Developmental Theories:
Intrinsic motivation

Zone of Proximal Development
(Vygotsky, 1930)

in BCI

1D

2D

3D


Feedback for learning

Behavioral Theories:
Extrinsic motivation

Cognitive Developmental Theories:
Intrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1948)

Zone of Proximal Development
(Vygotsky, 1930)


Mind in society: The development of higher psychological processes.
Feedback for learning

Behavioral Theories:
- Extrinsic motivation

Cognitive Developmental Theories:
- Intrinsic motivation

Motivational Theories:
- Extrinsic + intrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1948)

Zone of Proximal Development (Vygotsky, 1930)

Instructional Design - ARCS model (Keller, 1987)
Taxonomy of Intrinsic Motivations for Learning (Malone & Lepper, 1987)
Feedback for learning

Behavioral Theories:
Extrinsic motivation

Cognitive Developmental Theories:
Intrinsic motivation

Motivational Theories:
Extrinsic + intrinsic motivation

Law of effect (Thorndike, 1905)
Operand Conditioning and Reinforced Learning (Skinner, 1948)

Zone of Proximal Development (Vygotsky, 1930)

Instructional Design - ARCS model (Keller, 1987)
Taxonomy of Intrinsic Motivations for Learning (Malone & Lepper, 1987)

Malone

Keller
Feedback for learning

Social/ collaborative

Feedback for learning

Social/ collaborative

Playful

<table>
<thead>
<tr>
<th>Cue</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 s</td>
<td></td>
</tr>
<tr>
<td>1 s</td>
<td></td>
</tr>
<tr>
<td>2 s</td>
<td></td>
</tr>
<tr>
<td>3 s</td>
<td></td>
</tr>
<tr>
<td>4 s</td>
<td></td>
</tr>
<tr>
<td>5 s</td>
<td></td>
</tr>
<tr>
<td>6 s</td>
<td></td>
</tr>
<tr>
<td>7 s</td>
<td></td>
</tr>
<tr>
<td>8 s</td>
<td></td>
</tr>
</tbody>
</table>

Imagination of right hand movement

Relaxed state


Performance increases with user experience/motivation
Feedback for learning

Social/collaborative

Playful

Immersive/body ownership

Performance increases with confidence/motivation


Reminder: Why use VR/AR with BCI?
Desired user states:

1. Sense of Agency
2. Attention
3. Immersion
4. Pleasure

Self-rewarding (autotelic) experience
(intrinsic motivation)
1. Sense of Agency
2. Attention
3. Immersion
4. Pleasure
Self-rewarding (autotelic) experience
(intrinsic motivation)
“...It is when we act freely, for the sake of the action itself rather than for ulterior motives, that we learn to become more than what we were.”

– Mihaly Csikszentmihalyi, Flow: The Psychology of Optimal Experience
“...It is when we act freely, for the sake of the action itself rather than for ulterior motives, that we learn to become more than what we were.”

“...the self expands through acts of self forgetfulness.”

- Mihaly Csikszentmihalyi, Flow: The Psychology of Optimal Experience
“...It is when we act freely, for the sake of the action itself rather than for ulterior motives, that we learn to become more than what we were.”

“...the self expands through acts of self forgetfulness.”

“Enjoyment appears at the boundary between boredom and anxiety, when the challenges are just balanced with the person’s capacity to act.”

– Mihaly Csikszentmihalyi, Flow: The Psychology of Optimal Experience
Reaching Sense of Agency

“It is not the skills we actually have that determine how we feel but the ones we think we have.”

1. Body-ownership illusion

2. Adaptive biased feedback
Experiment: Tux Flow

14 participants
Engaging, Playful environment

14 participants
Engaging, Playful environment

Jeremy Frey
Experiment: Tux Flow

- 14 participants
- Engaging, Playful environment
- Clear goals and immediate feedback

Jeremy Frey
Experiment: Tux Flow

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation

Jeremy Frey
Experiment: Tux Flow

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation
Experiment: Tux Flow

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation

14 participants
Engaging, Playful environment
Clear goals and immediate feedback
Intrinsic + Extrinsic Motivation

Online adaptive task difficulty (biased feedback)
Experiment: Tux Flow

14 participants
Not Adapted Feedback

6 x 3 min

~8 min

14 participants
Adapted Feedback

EDUFlow Questionnaire
Experiment: Tux Flow

14 participants

Not Adapted Feedback

6 x 3 min

~8 min

14 participants

Adapted Feedback

6 x 3 min

~8 min

Jeremy Frey
Experiment: Tux Flow

14 participants

Not Adapted Feedback

6 x 3 min

~8 min

14 participants

Adapted Feedback

6 x 3 min

~8 min

Music Questionnaire

EDUFlow Questionnaire

EDUFlow Questionnaire
Experiment: Tux Flow

14 participants

Not Adapted Feedback

6 x 3 min

~8 min

14 participants

Adapted Feedback

6 x 3 min

~8 min

Music Questionnaire

EDUFlow Questionnaire

Music Questionnaire

EDUFlow Questionnaire

EDUFlow Questionnaire

EDUFlow Questionnaire

Music Questionnaire

Jeremy Frey
Biased Feedback (positive)

+ half distance
Biased Feedback (positive)

+ half distance
Biased Feedback (negative)

- half distance
Video
Results

1. Participants felt more in flow in the adapt condition

*Flow assessed with EduFlow Questionnaire (Heutte 2016)
Results

1. Participants felt more in flow in the adapt condition
2. Correlation between offline performance and flow state

*Flow assessed with EduFlow Questionnaire (Heutte 2016)

*Offline performance – k-fold cross-validation
1. Participants felt more in flow in the adapt condition
2. Correlation between offline performance and flow state

*Flow assessed with EduFlow Questionnaire (Heutte 2016)

*Offline performance – k-fold cross-validation

---

The Impact of Flow in an EEG-based Brain Computer Interface

J. Mladenovic\textsuperscript{1,2}, J. Frey\textsuperscript{1,3}, M. Bonnet-Save\textsuperscript{1}, J. Mattout\textsuperscript{2}, F. Lotte\textsuperscript{1}

\textsuperscript{1}Inria, Bordeaux, France
\textsuperscript{2}INSERM U1028, Lyon, France
\textsuperscript{3}Ullo, La Rochelle, France

E-mail: jelena.mladenovic@inria.fr

ABSTRACT: Major issues in Brain Computer Interfaces (BCIs) include low usability and poor user performance. This paper tackles them by ensuring the users to be in a state of immersion, control and motivation, called state of flow. Indeed, in various disciplines, being in the state of flow was shown to improve performances and learning. Hence, it may represent one of the major drawbacks for the advancement of BCIs.

A potential improvement in BCI is to acknowledge how difficult it can be to learn to produce mental commands (a very atypical skill) without a proper feedback about the progress one has made. In every discipline, a certain feedback on
Summary

- Evolution of feedback in BCI regarding educational theories
- Flow theory -- the next step
- VR/AR as means to reach flow in BCI and increase performance
Summary

- Evolution of feedback in BCI regarding educational theories
- Flow theory -- the next step
- VR/AR as means to reach flow in BCI and increase performance

Special thanks:
Doron Friedman, AVR Lab, IDC Herzliya, Israel
Fabien Lotte, Inria Bordeaux
Jeremie Mattout, CRNL
Jeremy Frey, Ullo
“Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person's skills, it usually begins to be intrinsically rewarding.”

– Mihaly Csikszentmihalyi, Flow: The Psychology of Optimal Experience
“Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person’s skills, it usually begins to be intrinsically rewarding.”

– Mihaly Csikszentmihalyi,
Flow: The Psychology of Optimal Experience

http://jmladeno.net
jelena.mladenovic@inria.fr
Methods and Materials

• 32 electrodes Brain Product;
• 2 class Motor Imagery BCI;
• CSP spatial filter;
• Probabilistic SVM classifier output modified in real-time providing biased feedback,
• 3 music songs
• Tux Racer, open source video game, being controlled by a virtual joystick connected to openvibe

NB. classifier accuracy presents user performance
Problem:
Not balanced groups. Non-adaptive group more advanced from the beginning than the adaptive group.
No corr between online perf and flow because of the diff of environments in train and test (graz and tux)