Augmented Feedback to Facilitate Motor Learning

Metodi e Didattiche delle Attività Motorie January 10th, 11th, 12th, 2017

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Studying material*

Scienze dello sport e della prestazione fisica

- Chapters 14-15 Motor Learning and Control Concepts and Applications, Magill R.A. (McGraw Hill).
- Chapter 7 Routledge Handbook of Motor Control and Motor Learning, Gollhofer A., Taube W., Nielsen J.B. (Routledge International Handbooks).
- Attentional focus and motor learning: review of 15 years. Wulf, 2013.
- Improving motor performance: selected aspects of augmented feedback in exercise and health. Laurer & Keller, 2014.
- A neuroscientific review of imagery and observation use in sport. Holmes & Calmels, 2008.
- Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. Sigrist et al., 2013.
- Lectures Prof. Cesari.

Studying material* Scienze motorie preventive ed adattate

- Chapters 15 Motor Learning and Control Concepts and Applications, Magill R.A. (McGraw Hill).
- Chapter 7 Routledge Handbook of Motor Control and Motor Learning, Gollhofer A., Taube W., Nielsen J.B. (Routledge International Handbooks).
- Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. Sigrist et al., 2013.

Final exam:

Scienze dello sport e della prestazione fisica

- 6-5 People divided in 6 groups
- Each group will present a scientific article (see list provided)
- Evaluation:
 - 1. Presentation of the study (see grading template) **20'**
 - 2. Link to the topics discussed during the lectures*
 - 3. Link to practical interventions <u>with</u> examples
- Each group component <u>must</u> equally contribute to the presentation, linkage to lectures topics and practical interventions

Final exam:

Scienze motorie preventive ed adattate

- 6-5 People divided in 8 groups
- Each group will present a scientific article (see list provided)
- Evaluation:
 - 1. Presentation of the study (see grading template) **15'**
 - 2. Link to the topics discussed during the lectures*
 - 3. Link to practical interventions <u>with</u> examples
- Each group component <u>must</u> equally contribute to the presentation, linkage to lectures topics and practical interventions



Types of Feedback

- 1. Intrinsic Internal Feedback
- 2. Intrinsic External Feedback
- 3. Augmented (Extrinsic) Feedback

Why Augmented Feedback (AF)?

It is better controllable in quantitative terms and can be modified in experimental setting.

In contrast to intrinsic internal & external feedback, the intensity of AF is better controlled on an inter-individual basis.

It is very powerful to facilitate motor learning.

AF and different processes of learning

Reinforcement learning

- Formation of directed action selection based on rewards.
- AF may be provided to facilitate (reinforce) the change of behavior.
- \succ Information: failure or success.
- > Information provided may result limited.

Wolpert et al., 2011

AF and different processes of learning

Error-based learning process

- Error as a source to drive motor learning
- AF can be easily and extensively used to minimize the error.

Wolpert et al., 2011

AF and different processes of learning

Use-dependent learning

- Motor behavior can change by pure repetition of a (a) specific movement(s).
- Learner who performs the movement(s) does not receive any information about the outcome.
- ➤ Thus, AF is by definition not part of the process of use-dependent learning.

Wolpert et al., 2011

Roles of AF in skill acquisition

Facilitate achievement of the action goal of the skill.

- ✓ AF provides information about the action in progress or just completed.
- ✓ Learner can determine whether she/he is doing the movement correctly.
- AF can help to achieve the skill goal more quickly and easily that without external information.

Roles of AF in skill acquisition

Motivate the learner to continue striving toward a goal.

- ✓ Learner uses AF to compare her/his own performance to a performance goal.
- Then, the learner decides to continue trying, change the goal or stop performing the activity. (Motivation & motor learning)

Types of Augmented Feedback:

- 1. Knowledge of Result (KR)
- 2. Knowledge of Performance (KP)
- 3. BioFeedback (BF) (subtype of KP)

Knowledge of Result (KR)

Information given to the learner after the completion of the movement, which describes the outcome of the movement in terms of the movement goal



Knowledge of Performance (KP)

Information that describes the quality of the movement pattern that led to the performance outcome.







BioFeedback (BF)

Augmented form of intrinsic internal feedback related to the activity of physiological processes:

- Heart rate
- VO₂
- EMG







Does Augmented Feedback facilitate motor learning?







1. Some skill performance contexts do not provide intrinsic external feedback.



- 2. Because of injury and/or diseases
 - ✓ Stroke
 - ✓ Cerebral palsy
 - ✓ PD

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 - ✓ Stroke
 - ✓ Cerebral palsy
 - ✓ PD

AF and cerebral palsy





Intrinsic internal feedback provides the necessary information but the learner is not capable to use the feedback.
 e.g. Novices





AF can be essential and <u>enhance</u> skill acquisition

- 4. It facilitates motor skill acquisition beyond what could be achieved without AF.
 - ✓ Ceiling effect ✓ Elite athletes

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 - ✓ Ceiling effect ✓ Elite athletes

One-hand basketball shooting w/ no-dominant hand.

- Verbal KP
- Verbal encouragement



Wallace and Hagler, 1979

AF may **not be needed** or **hinder** skill learning

- Learner becomes dependent on AF
- Feedback-guidance hypothesis (Salomoni et al., 1984; Swinnen 1996; Magill 2007)
- Presentation of erroneous AF
- Concurrent AF
- AF given too frequently during practice

Kinetics feedback ✓ Forces ✓ Torques ✓

Kinetics feedback ✓ Forces ✓ Torques ✓

- Peacock et al. (1981)
 - ✓ Force AF during isometric contractions
- Hopper at al. (2003)

✓ Force AF increased the power output during leg press

- Mornieux et al. (2008)
 - ✓ Pedal force AF improves cycling effectiveness

Kinematics feedback

✓ Velocity

 \checkmark

- ✓ Joints Angles
- Eriksson et al. (2011)
 - Visual AF about COM displacement and step-frequency during running resulted w/ improved of mechanical work.
- Wood et al. (1992)

✓ Visual AF can have positive effect on learning a golf shot

- Moran et al. (2012)
 - \checkmark Visual AF about speed of tennis serve.
 - ✓ Without AF people were not able to rate their performance

Kinematics feedback



Taube et al. (2008) assessed the influence of visual AF on stability.

Results showed a reduced COP displacement when subjects aimed with laser pointer on a stationary target both on stable and unstable surface

Kinematics feedback

- Onate et al. (2001)
 - ✓ Vertical GRF reduced when using video-AF
 - \checkmark Findings relevant in the prevention of stress fractures.
 - ✓ Retention?
- Crowell et al. (2010)
 - Real-time visual AF reduced the loading of lower extremities during treadmill running.

BioFeedback (BF)

Augmented form of intrinsic internal feedback related to the activity of physiological processes:

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EMG-based AF and cerebral palsy





EMG-based AF and cerebral palsy





Liyanagamage, Bertucco, et al., 2016





Liyanagamage, Bertucco, et al., 2016

EMG-based AF and cerebral palsy



Task performance was unchanged within groups post vibration

Liyanagamage, Bertucco, et al., 2016


EMG -based **BF**

Ekblom & Eriksson (2012)

Subjects were asked to increase EMG activity through visual BF.

Results showed an increase of knee extensor strength compared to when no BF was provided



Others form of BF

Sitaram et al. (2012) showed that subjects who trained with real-time fMRI learned to increase their blood oxygen level dependent (BOLD) response in the ventral premotor cortex.

Landers et al. (1991), subjects were capable to modify EEG activity in the left or right hemispheric area independently before shooting.

These neurophysiological adaptations resulted in a reduction in movement errors.

Others form of BF

Daniels & Landers (1981) showed that heart beat, presented as auditory BF, helped shooters learn to squeeze the rifle between heart beats.

Heart beat as useful and powerful BF for sport training, rehabilitation and fitness.

AF & rehabilitation

AF can be helpful to facilitate motor skill acquisition after brain damage, trauma and neurological injury

Studies results from healthy population



Do not imply they can be completely transferred to pathological conditions

(Winstein, 1991)











Visual Tactile

Auditory

Multi-modal

Sigrist et al, 2013

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AF about errors or correct aspects of Performance?

Research evidence has shown that error information is more effective for facilitating skill learning:

- Durability
- Transfer

Information about correct performance serves better to motivate the person to continue

KP vs KR

KR will be beneficial for skill learning:

- Learners often use KR to confirm their own assessment of the intrinsic feedback.
- When learners cannot determine the outcome of the performance.
- When practitioners provides only KR to elicit a discovery learning practice in which learners are encouraged to engage in problem solving activity.

KP vs KR

KP will be beneficial for skill learning:

- Skills must be performed according to specific movement characteristic.
- Specific movement components of skills that require complex coordination.
- The goal of the action is a kinematic, kinetic or specific muscle activity
- KR is redundant.

Qualitative vs Quantitative AF

Early stage of learning \rightarrow qualitative information

✓ Easier way to make a first approximation of the required movement

Advanced stage of learning \rightarrow quantitative information

✓ When quantitative information becomes more valuable because it enables the learner to refine characteristics of performing skills

Amplification of error as AF

MAE = Method of Amplification Error

Correcting tool for the identified errors

Learning occurs by exploiting intrinsic feedback during the amplified-error performance and comparing it with the previous trials

(Milanese et al., 2008)

Amplification of error as AF

Main error vs Secondary error



Subjects improved the "rear-foot strike" by amplifying only the **main** error

Corte et al. 2015

1 - Descriptive and prescriptive KP

Descriptive KP

- Simply describe the error

Prescriptive KP

 describe the error & also tells the person what to do to correct it

Which type better facilitate motor learning?

2 – Video-recording as AF

Popular AF used in sport practice either in elite and novice learners



Guadagnoli et al., 2002

2 – Video-recording as AF

Research evidence suggest that video-replay AF transmit <u>certain type of performance</u> <u>related information</u> more effectively than other type

Is it always useful?

2 – Video-recording as AF

Research suggests that video-replay facilitates learning in those that can readily observe and catch the useful performance information



Concurrent & Terminal AF

- Concurrent AF
- AF provided during the performance

Terminal AF

- AF provided after the person has completed the performance

Concurrent & Terminal AF

Research literature suggests that there is not a unequivocal answer whether one of the two types of AF lead to a better learning facilitation.

Concurrent & Terminal AF

Studies (Linter, 1991; Linter et al., 1990) suggest that for the concurrent AF to be affective, it must facilitate the learning of the critical feature or relationships in the task as specified by the internal intrinsic feedback.

Frequency of presenting AF

Reduced frequency benefit

 optimal frequency for AF is not 100% (Winstein and Schmidt, 1990)
Fading technique

Frequency of presenting AF

(Winstein and Schmidt, 1990)



Frequency of presenting AF

Theoretical implication of frequency effect:

- Feedback-guidance hypothesis

Performance-based Bandwidths

AF is given before or after a threshold value

Performance-based Bandwidths

AF is given before or after a threshold value

Useful technique of **individualizing** the systematic reduction of the frequency of AF

Guideline to the practitioner when to provide AF

Dual process: error-based + reinforcement

Self-Selected Frequency

Learner receives AF only when he or she asks for it

Chiviakowsky & Wulf (2005, 2007) showed that subjects asked AF only for successful trails.

Self-Selected Frequency

Learner receives AF only when he or she asks for it

Chiviakowsky & Wulf (2005, 2007) showed that subjects asked AF only for successful trails.

1- use of AF in this way allows beginners to engage their own problem-solving.

2- excellent evidence that learners use AF as a source of motivation to continue to practice

Summary or Averaged AF



Schmidt et al., 1989

Summary or Averaged AF

Subtype of AF reduced frequency (Sidaway et al., 1991)

Subliminal AF

Well-described phenomenon that we may respond to features of our surrounding without being aware of them. (Goodale, 2008; Pessiglione et al., 2007)

We perceive but we do not feel it!!

Subliminal AF

Subliminal vibrotactile stimulation can lead to increase postural stability and balance in young and elderly. (Priplata et al., 2002, 2003)

Still an open research field

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- ✓ AF about errors or correct aspects of Performance
- ✓ KP vs KR
- ✓ Qualitative vs Quantitative AF
- ✓ MAE
- ✓ Descriptive and prescriptive KP
- ✓ Video-recording
- ✓ Concurrent & Terminal AF
- ✓ Frequency of presenting AF
- Performance-based Bandwidths
- ✓ Self-Selected & Summary Frequency
- ✓ Subliminal AF

Attentional focus and motor learning

Attentional focus and motor learning

Internal focus

Attention directed to body movements

External focus

Attention directed to the effect of the movement

Attentional focus: balance



Internal focus

Learners were instructed to try to exert force on the **<u>outer foot</u>**.

External focus

Learners were instructed to try to exert force on the **outer wheel**.



Wulf et al., 1998
Attentional focus: accuracy



Internal focus

Focus on the hands

External focus

Focus to the club and/or ball trajectory.

Enhance of accuracy

Wulf and Su, 2007

Attentional focus: accuracy

Internal focus

Strike



Focus on the foot that contact the ball External focus

Focus to the part of the ball that the player would strike

Enhance of accuracy

Zachry, 2007

Attentional focus: accuracy



Internal focus Focus on the effector

External focus

Focus on the outcome

Enhance of accuracy

Lohse, 2012

Attentional focus: movement efficiency

Internal focus

Focus on the wrist



Focus on the hoop

Enhance of accuracy Reduced EMG

Zachry et al., 2005



Attentional focus: max force production

Isokinetic MVC

Internal focus

Focus on the arm muscle

External focus

Focus on the crank bar of dynamometer

Greater peak joint torque

Marchant et al., 2009

Attentional focus: max force production

Internal focus

Extend knee as rapidly as possible

Standing long jump



External focus

Jump as far past the start line as possible

Average greater jumping distance

Porter et al., 2010

Attentional focus: speed and endurance

Internal focus Pulling their hands back

External focus

Pushing the water back

Increased swim speed

Freudenheim et al., 2010

Crawl



Attentional focus: speed and endurance

Dribbling task



Internal focus Focus on the technique

External focus

Position on the ball in relation to the cones

Increased speed

Jackson et al., 2006

Attentional focus: speed and endurance

Skilled runners



Internal focus Running form or breathing

External focus

Video display that simulated running outdoors

Reduced O₂ consumption

Schücker et al., 2009

Attentional focus: kinematics

Internal focus

Novice rowers



Keep your hands level during the recovery

External focus

Keep the blade level during the recovery

Improvement of the technique

Parr & Button, 2009

How does the attentional focus affect the performance and learning?

Constrained action hypothesis

Internal focus induces a conscious type of control, causing individuals to constrain their motor system by interfering with automatic control processes.

An external focus promotes a more automatic mode of control by utilizing unconscious, fast, and reflexive control processes.

Wulf et al., 2001

How does the attentional focus affect the performance and learning?

Constrained action hypothesis

Or/and?

Reinforcement learning

How does the attentional focus affect the performance and learning?

External focus

"Equifinality" and motor synergies (Bernstein's problem)

> Internal focus Constrained context

External focus During movement VS KP After performance

vs KP

Motor exploration