



Incorporating psychomotor skills training into GIFT tutors: “outside the box” authoring support

Debbie Brown¹

Benjamin Goldberg, Ph.D.²

Benjamin Bell, Ph.D.¹

Elaine Kelsey¹

¹ Eduworks Corporation, Corvallis, OR

² U.S. Army Research Laboratory, HRED-ATSD, STTC, Orlando, FL

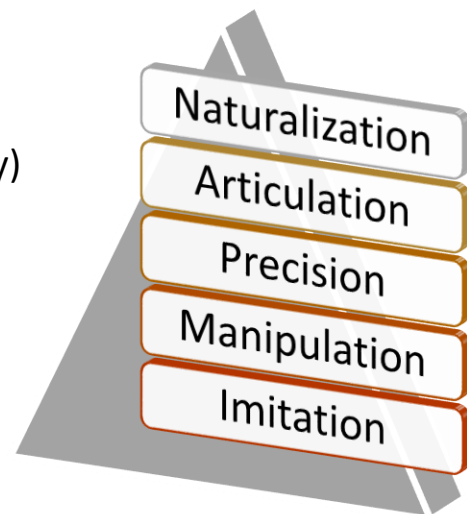
Intelligent Tutoring Challenges

- Army embracing ITS for scalable, replicable training
 - In STE Statement of Need
 - Still costly, time-consuming; Need affordable, replicable process
- Solution? ITS Authoring Tools
 - Improving, but still...
 - Limited in scale, utility, usability, instructional value
- Gaps? Psychomotor skills foundational to full-spectrum ALM
 - Vital core of many 21st Century Soldier Competencies
 - Adaptability & initiative
 - Comprehensive fitness
 - Tactical & technical competencies



How Are Psychomotor Skills Different?

- “Psychomotor” is not a homogenous label
 - Simpler, manual tasks (polishing boots)
 - More procedural tasks (loading artillery, performing precision drill routine)
 - Highly complex psychomotor tasks (landing CH-47, emergency cricothyrotomy)
- Existing frameworks include:
 - Simpson (1972) -- Seven major categories of psychomotor behaviors.
 - Harrow (1972) – Six functional categories
 - Dave (1970): Imitation; Manipulation; Precision; Articulation; Naturalization
- Our synthesis of a taxonomy of military-relevant psychomotor skills
 - Training-relevant characteristics that influence how authoring tool would be composed.
 - E.g. learning objectives, sequencing, instructional strategies, remediations, assessments.



Psychomotor Domain
Based on Dave (1970)

Psychomotor Skill Acquisition Model

Level	Definition	Example
Observing	Active mental attending of a physical event.	The learner watches a more experienced person. Other mental activity, such as reading may be a part of the observation process.
Imitating	Attempted copying of a physical behavior.	The first steps in learning a skill. The learner is observed and given direction and feedback on performance. Movement is not automatic or smooth.
Practicing	Trying a specific physical activity over and over.	The skill is repeated over and over. The entire sequence is performed repeatedly. Movement is becoming automatic and smooth.
Adapting	Fine tuning. Making minor adjustments in the physical activity in order to perfect it.	The skill is perfected. A mentor or a coach is often needed to provide an outside perspective on how to improve or adjust as needed for the situation.

Generalized/Combined Phases of Psychomotor Domain Learning

Exemplar Case: Existing Psychomotor ITS

- ITS Exemplar: Advanced Marksmanship Trainer
 - Exemplar serves as envisioned product of authoring process facilitated by PSTAAT
 - Process used to develop exemplar analyzed for requirements, workflows
 - “What would a tool need to look like to have enabled the development of this ITS?”
- Benefits
 - Target outcome frames design of the authoring tool
 - Workflows streamlined with semi-automation and templates
 - Methods from exemplar used as Illustrations and examples by the authoring agent



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PSTAAT in GIFT

The screenshot displays the GIFT Course Creator interface. The top navigation bar includes 'Take a Course', 'Learner Profile', 'Course Creator', and 'Publish Courses'. The user is logged in as 'winonadeb'. The main workspace shows a course flow diagram for 'Psychomotor Demonstration' with the following steps:

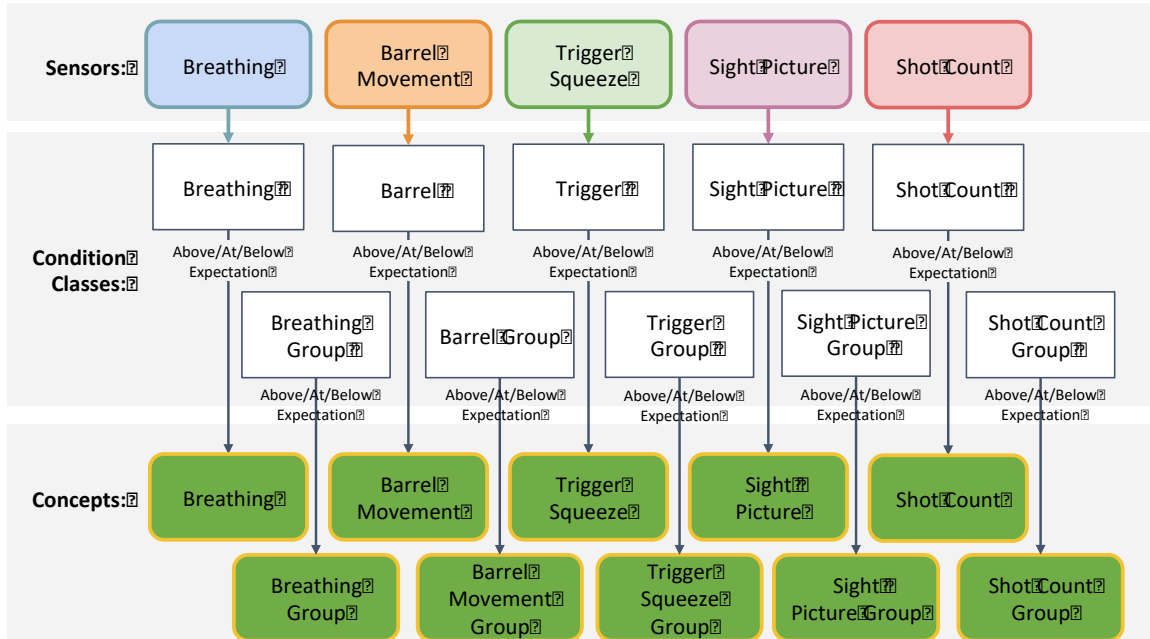
- Information as Text** (Welcome) → **PowerPoint** (Marksmanship Review)
- Psychomotor Activity** (Marksmanship Training) → **YouTube Video** (Review of Shoot/Don't Shoot Guidelines)
- Psychomotor Activity** (Shoot/Don't Shoot Practice) → **+** (Placeholder for a new activity)

The 'Psychomotor Activity' boxes are highlighted with blue dashed borders. A 'Media' sidebar on the left lists various objects like 'Conversation Tree', 'Question Bank', 'Media Collection', 'Adaptive Courseflow', 'Adaptive Courseflow', 'Psychomotor Activity', 'Structured Review', 'Virtual Battle Space', 'TC3', and 'DE Testbed'. A right-hand panel shows configuration options for 'Marksmanship Training', including 'Concepts to cover' (Marksmanship, Shoot/Don't Shoot), 'Generalized Model' (Observation, Imitation, Practice, Adaptation), and 'PSTAAT Agent says'.

- Leverages GIFT's *Course Creator*
- Creating a Psychomotor *course object* for integration w/GIFT course authoring

Psychomotor: Making sense of sensors

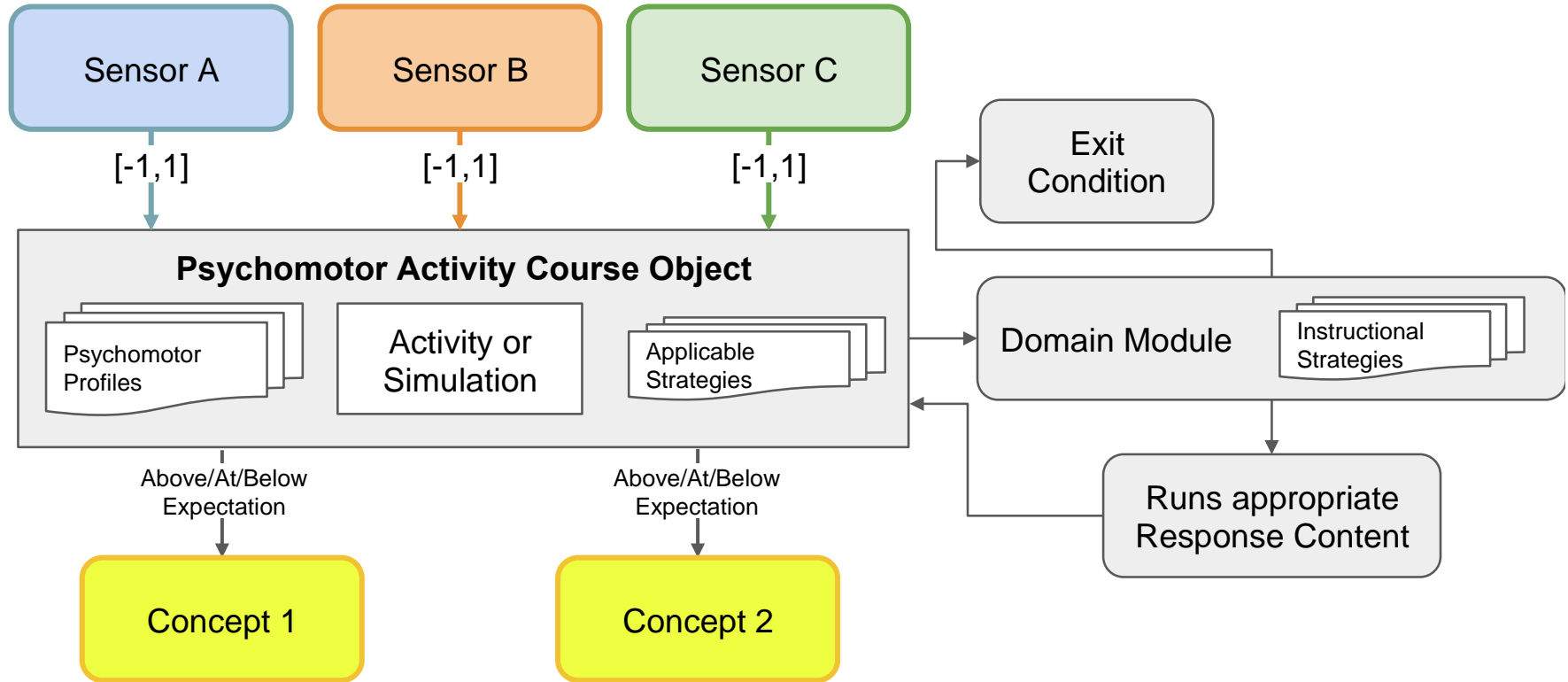
- Separate *sensor configuration* from *instructional design*
- Help author map sensors to concepts
- Generalize approach used in exemplar



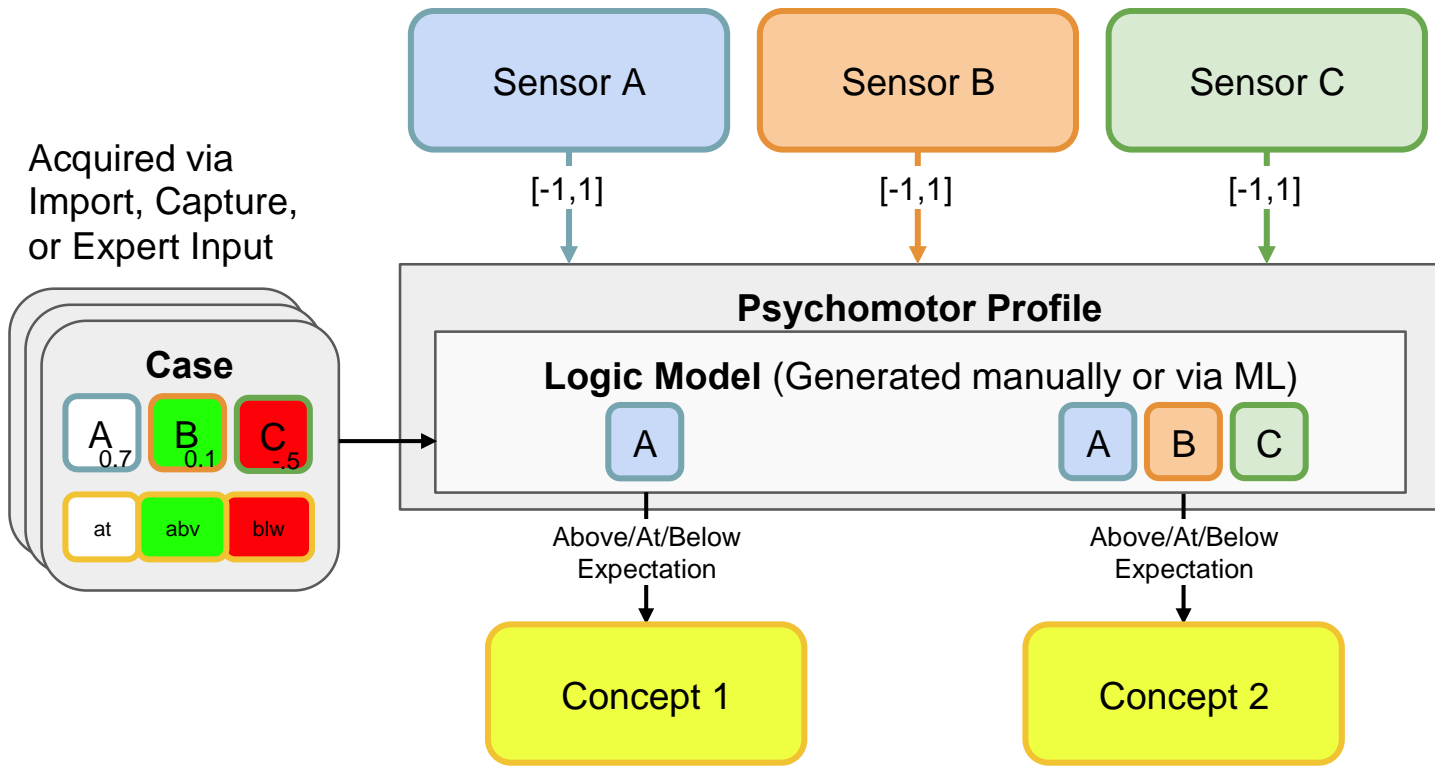
Sensor Configuration:
Psychomotor Profile

Instructional Design:
Psychomotor Activity

Psychomotor Activity Course Object



Psychomotor Profile



Psychomotor Activity Course Object

Author adds a *Psychomotor Activity* course object to a course.

Author provides a name for the activity and the Psychomotor Activity editor is displayed.

The screenshot displays the course creation interface. At the top, navigation tabs include 'Take a Course', 'Learner Profile', 'Course Creator', and 'Publish Courses'. The user 'winonadeb' is logged in. The 'Course Properties' sidebar on the left shows 'Course Objects' with a grid of icons: Media Collection, Adaptive Courseflow, Adaptive Courseflow (9013-01), Psychomotor Activity, Structured Review, Virtual Battle Space, TC3, and DE Testbed. An orange arrow points from the 'Psychomotor Activity' icon in the sidebar to a 'Psychomotor Activity' object in the main course flow area. The main area shows a dashed box containing a plus sign and the 'Psychomotor Activity' icon. An 'Information as Text' object with the text 'Example Guidance' is connected to the dashed box. A trash can icon is visible in the bottom right corner of the main area.

Building the Psychomotor Activity

The screenshot displays the 'Course Creator' interface for 'PSTAAT Walkthrough'. On the left, the 'Course Objects' panel lists various components like 'Conversation Tree', 'Question Bank', 'Media Collection', 'Adaptive Courseflow', 'Psychomotor Activity', 'Structured Review', 'Virtual Battle Space', 'TC3', and 'DE Testbed'. The main workspace shows a flow diagram where 'Information as Text' (Example Guidance) points to a 'Psychomotor Activity' (Shot Practice). A dashed box with a plus sign indicates where to add new objects. On the right, the 'Shot Practice' configuration panel is open, showing 'Concepts to cover' (Breath Control, Barrel Movement, Trigger Squeeze, Group Size) and a 'Generalized Model' with phases: Observation, Imitation, Practice, and Adaptation. An 'Options' section is also visible. At the bottom, the 'PSTAAT Agent says' section provides guidance: 'Great, now we'll configure the tutor's behavior during each phase of instruction. Expand the first phase in the list above to begin. Learn more...'. A yellow callout box states: 'The "Generalized Model" is the default psychomotor domain instructional approach.'

Author selects concepts and a Psychomotor Domain Instructional Approach.

Agent auto-generates corresponding instructional phases with guidance.

Building the Psychomotor Activity

The screenshot displays the Course Creator interface for a course titled "PSTAAT Walkthrough". On the left, the "Course Objects" panel lists various content types, with "Psychomotor Activity" selected. The main workspace shows a flow diagram where an "Information as Text" object (containing "Example Guidance") is linked to a "Psychomotor Activity" object (containing "Shot Practice"). A dashed box with a plus sign indicates a new phase to be added. On the right, the configuration panel for the "Shot Practice" activity is shown. It includes a "Generalized Model" section with "Observation" and "Imitation" phases. The "Imitation" phase is currently selected, and a dropdown menu is open, showing a list of performance profiles. An orange arrow points from the text on the right to the dropdown menu, indicating the selection of a profile.

Course Properties

Take a Course | Learner Profile | Course Creator | Publish Courses | Help | winonadeb

Course Objects

- Conversation Tree
- Question Bank
- Media Collection
- Adaptive Courseflow
- Adaptive Courseflow (9013-2)
- Psychomotor Activity
- Structured Review
- Virtual Battle Space
- TC3
- DE Testbed

Drag objects onto the course flow area to add them to your course.

Media

Psychomotor Activity
Promotes the development of Psychomotor Task skills with increasing complexity and delivers remediation based on learner state.

Information as Text
Example Guidance

Psychomotor Activity
Shot Practice

+

Shot Practice

- Barrel movement
- Trigger Squeeze
- Group Size

Generalized Model

Observation
Marksmanship Kneeling Prof [Disable]

Show message on completion

Imitation
Marksmanship Imitation Prof [Disable]

Select a profile...

- Marksmanship Imitation Profile
- Marksmanship Kneeling Profile
- Marksmanship Precision Profile
- Marksmanship Prone Profile
- Unity Shoot/Don't Shoot Acceptable Outcomes
- Unity Shoot/Don't Shoot Expert Outcomes

Create a profile...

Show content instead...

Select an existing performance profile for the Imitating phase of instruction, or create a new one.

Learn more...

For each phase, Author selects a Psychomotor Profile from list to reuse or edit.

Once a profile is set, instructional strategies may be defined for the phase.

Building the Psychomotor Activity

Instructional strategies for Imitating Marksmanship Imitation Profile

Your tutor will be able to detect all of these learner states for the concepts being measured. Let's tell the tutor how it should respond in each situation by adding instructional feedback. Click on the spaces below to define feedback for each concept.

Concepts	Below Expectation	At Expectation	Above Expectation
Breathing	<input checked="" type="checkbox"/> Remediation Set	<input checked="" type="checkbox"/> Feedback Set	<input type="checkbox"/> No feedback
Trigger Squeeze	<input checked="" type="checkbox"/> Remediation Set	<input type="checkbox"/> No feedback	<input type="checkbox"/> No feedback
Barrel Movement	<input checked="" type="checkbox"/> Remediation Set	<input type="checkbox"/> No feedback	<input type="checkbox"/> No feedback
Group Size	<input type="checkbox"/> No remediation	<input type="checkbox"/> No feedback	<input type="checkbox"/> No feedback

Copy Responses

Save Responses

Edit Profile

Cancel

Author can copy strategies from another phase already edited

Author can review current performance profile settings

Help | winonadeb

Shot Practice

- Barrel movement
- Trigger Squeeze
- Group Size

Generalized Model

Observation

Marksmanship Kneeling Prof [Disable]

Show message on completion

Imitation

Marksmanship Imitation Prof [Disable]

Practice

Adaptation

Options

PSTAAT Agent says: Example

You may design the tutor to respond to all or none of these states, but keep in mind that the more instructive your feedback, the more likely the learner will be able to make performance improvements.

Agent generates placeholder instructional strategies for all possible learner performance scenarios.

Author designs instructional strategies for each possible performance scenario.

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Building the Psychomotor Activity

Edit Performance Profile

Performance Profile Info

[Duplicate Profile](#) | [Export Profile](#) | [Delete](#)

Marksmanship Imitation Profile

This profile represents sensor configurations in the AMT Marksmanship Tra

Practice Applications

Target Simulator

Unity WebGL

[edit](#) | [delete](#)

[Add Application](#)

Concepts and Sensors

Breathing

Trigger Squeeze

Barrel Movement

Group Size

+

[Import Cases](#) | [Collect Cases](#)

Sensor configuration for Breathing

[Copy Configuration](#) | [Delete Configuration](#)

Above Expectation

BioHarness Sensor

0.189

Enabled

At Expectation

BioHarness Sensor

0.284

Enabled

[Add / Remove Sensors](#)

Other values will be considered **Below Expectations**

[Save Changes](#)

[Cancel](#)

Each concept is a tab, with one or more sensors per concept.

Author may choose to tweak the settings of the profile in a phase and save as a new one.

Author can save changes for all uses of the profile, or provide a new name.

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Building the Psychomotor Profile

New Performance Profile

Performance Profile Info

Continue

Save Changes

Cancel

Author should provide a unique and meaningful name and description for the new profile, knowing it can be reused later

The screenshot shows a software interface with a window titled 'Shot Practice'. It features several sections: 'Imitation', 'Practice', and 'Adaptation'. Each section has a dropdown menu and a 'Disable' button. The 'Adaptation' dropdown is open, showing a list of profiles including 'Marksmanship Imitation Profile', 'Marksmanship Kneeling Profile', 'Marksmanship Precision Profile', 'Marksmanship Prone Profile', 'Unity Shoot/Don't Shoot Acceptable Outcomes', and 'Unity Shoot/Don't Shoot Expert Outcomes'. The 'Create a profile...' option is highlighted in blue. Below the dropdown, there is a lightbulb icon and text: 'Show content instead... profile for this phase of instruction, or create a new one.' and a 'Learn more...' link.

Author can create new Psychomotor Profiles by selecting “Create a profile...”

Building the Psychomotor Profile

Author has option to create a profile manually in an agent-guided process.

Author starts by selecting a TA and concepts to be covered in the profile.

New Performance Profile

Performance Profile Info

Duplicate Profile | Export Profile | Delete

Marksmanship Adaptation Profile

Performance metrics for use during the adaptation phase in Marksmanship T...

Practice Applications

Add Application

Target Simulator

Unity WebGL

edit | delete

Add Concepts

Select all of the concepts to be covered in this profile:

- Breathing
- Barrel Movement
- Trigger Squeeze
- Group Size
- Best Practices

Save

Cancel

Help | winonadeb

Shot Practice

marksmanship kneeling prof

Show message on completion

Imitation

Marksmanship Imitation Prof

Disable

Show message on completion

Practice

Marksmanship Imitation Prof

Disable

Show message on completion

Adaptation

Create a profile

Disable

Show message on completion

Options

PSTAAT Agent says:

Example



Now that we know where training will take place, let's set up the concepts that will be assessed during performance.

[Learn more...](#)

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Building the Psychomotor Profile

New Performance Profile

Performance Profile Info

[Duplicate Profile](#) | [Export Profile](#) | [Delete](#)

Marksmanship Adaptation Profile

Performance metrics for use during the adaptation phase in Marksmanship T,

Practice Applications

[Add Application](#)

Target Simulator

Unity WebGL

[edit](#) | [delete](#)

Concepts and Sensors

[Import Cases](#) | [Collect Cases](#)

Breathing Trigger Squeez Barrel Movement Group Size Best Practices +

Sensor configuration for Breathing

[Copy Configuration](#) | [Delete Configuration](#)

[Add / Remove Sensors](#)

[Save Changes](#)

[Cancel](#)

Author can copy a concept configuration from another profile, or clear the current configuration and start over.

Author manually adds sensors to each concept.

Author has option to let agent generate a performance model by importing or collecting performance data.

More details to come...

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Building the Psychomotor Profile

Agent incorporates selected sensor(s) in the concept tab(s).

Author enters sensor thresholds for **Above** and **At Expectation** levels of performance.

Sensors can be disabled, added, removed, and combined.

The screenshot displays the 'New Performance Profile' interface. On the left, under 'Practice Applications', 'Target Simulator' is selected. Below, 'Concepts and Sensors' shows 'Breathing' selected. The 'Sensor configuration for Breathing' section is divided into 'Above Expectation' and 'At Expectation' levels. The 'Above Expectation' level has 'True if all are met' and lists 'BioHarness Sensor' (0.189) and 'Oxygen Sensor' (0.9), both enabled. The 'At Expectation' level has 'True if any are met' and lists 'BioHarness Sensor' (0.284) and 'Oxygen Sensor' (0.6), with the latter disabled. A yellow callout box points to the 'Enabled' checkboxes and the 'Add / Remove Sensor' button. On the right, a 'Shot Practice' window shows a list of concepts: 'marksanship kneeling prof', 'Imitation', 'Practice', and 'Adaptation', each with a 'Disable' button. A 'PSTAAT Agent says' section at the bottom right provides instructions on configuring sensor readings for different performance levels.

Example Training Application

- Purpose: Serves as the TA that a PSTAAT author intends to use in an ITS
- Illustrates authoring configuration for psychomotor instructional phases
- Demonstrates both motor and psychomotor course modules



Marksmanship only - Motor

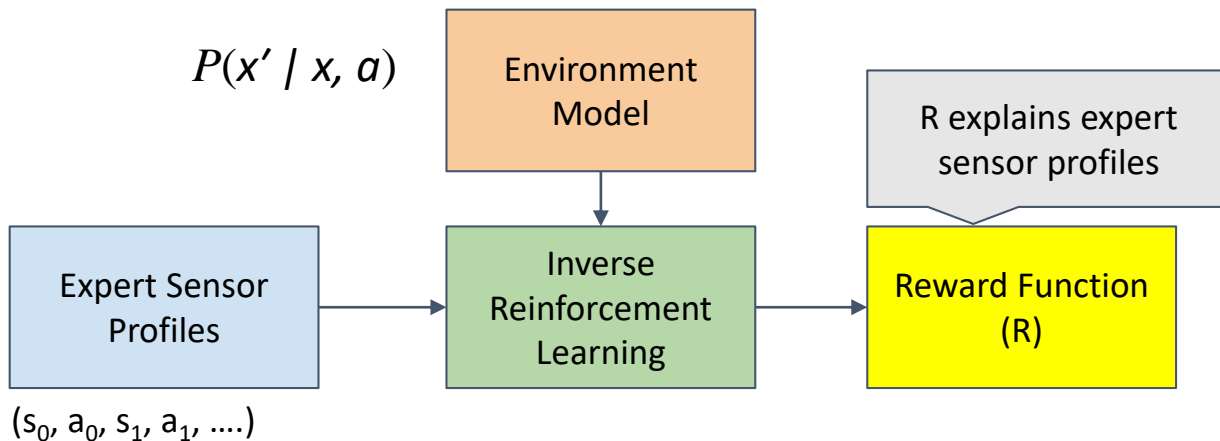


Shoot/Don't Shoot scenario - Psychomotor

Sensor Calibration, Performance Assessment

- Employs ML to help author derive appropriate performance ranges
 - ML analyzes, classifies sensor data using Inverse Reinforcement Learning (IRL)
 - Automates detection of sensor thresholds (Expert/Novice) based on expert feedback
- Processes raw sensor data w/integration of ML libraries via Spark instance
 - Leverages RapidMiner integrations with GIFT
- Applies range of possible models to test data generated in performance modeling
 - Attempts to derive best-fit model for given sensor/performance outcome combinations
- Uses data from cases to learn reward function(s) characterizing expert behavior
 - Learns to distinguish expert from novice behavior (*i.e.*, clustering).
- Once training data has produced an ML model, we auto-generate logic model
 - Evaluates performance during task execution
 - Can also be additional source of feedback (*e.g.*, “reduce breathing rate”)

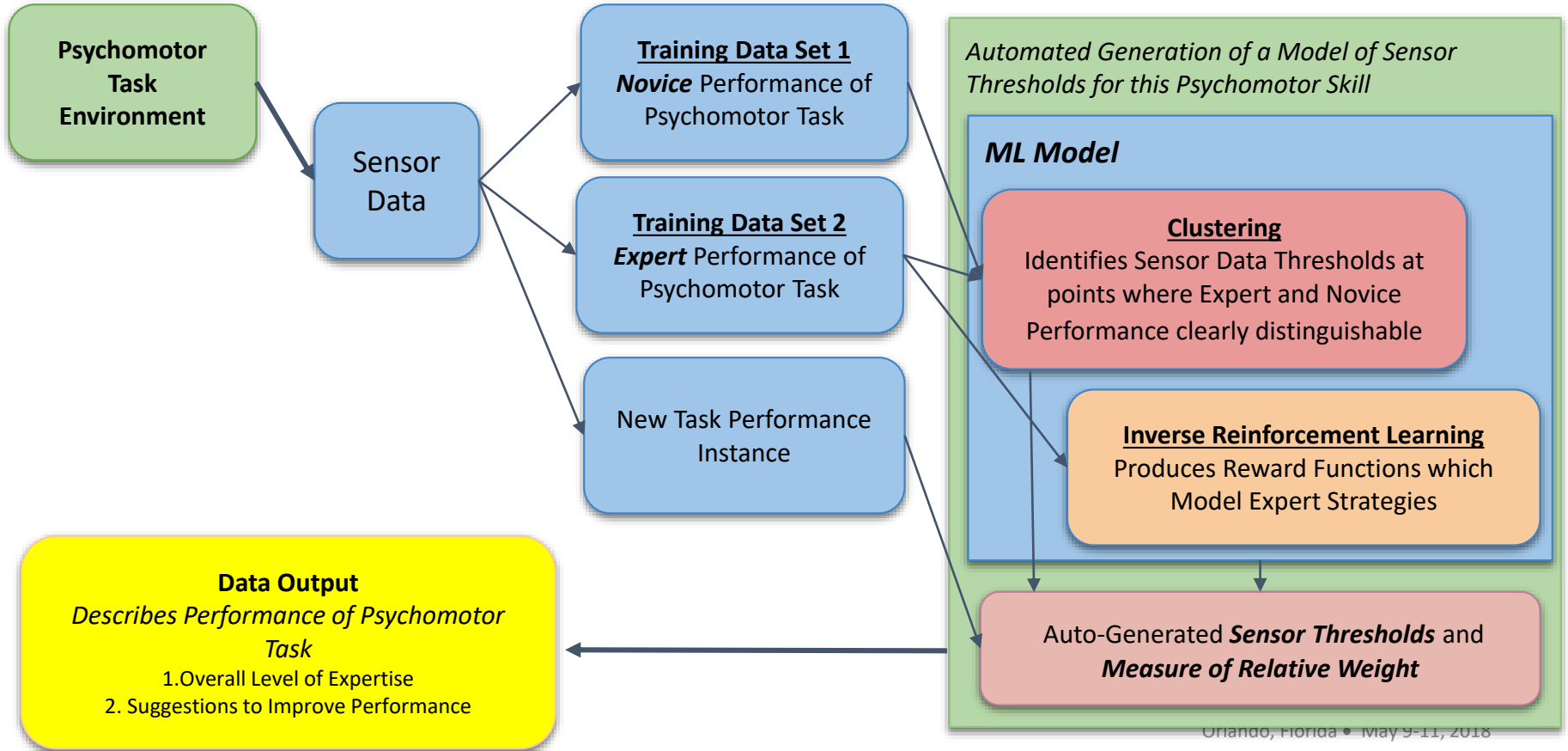
Inverse Reinforcement Learning



Motivation for Inverse RL

- Apprenticeship Learning through Inverse RL has proven **effective in modeling complex psychomotor task performance** (e.g. bee foraging, songbird vocalization, helicopter flying)
- Reward Function provides both a succinct definition of the task and a **means for providing human-interpretable feedback on performance** (i.e. what does the performer need to change to better maximize the reward function?)

Machine Learning Data Flow



Learned Reward Function Example

- Maximum reward function in a given partition represents the most 'expert' performance for that segment of the task.

```
{  
  "Activity": -0.06174977183568904,  
  "AuxADC1": -0.05642922419001644,  
  "AuxADC2": 0.026856873410421617,  
  "AuxADC3": 0.08018542257772318,  
  "BR": -0.009313253853200212,  
  "BRAmplitude": -0.06904420238668887,  
  "ECGAmplitude": 0.0025587747983270015,  
  "HR": -0.004541751012320322,  
  "LateralMin": 0.016449063056355934,  
  "LateralPeak": 0.09200014916271315,  
  "PeakAccel": 0.072626472176848,  
  "Posture": 0.001315607688712389,  
  "SagittalMin": 0.002698566758107354,  
  "SagittalPeak": 0.06608117196168137,  
  "SkinTemp": 0.011988825584386784,  
  "VerticalMin": -0.03392192334684739,  
  "VerticalPeak": -0.035934888114066296  
}
```

Example

- Overall performance increases as breath rate, amplitude & some torso movements minimized, while other torso movements maximized
- Heart rate, breath rate less important

Innovation in Machine Learning

- Novel application of Apprenticeship Learning via Inverse Reinforcement Learning
 - *Combined data from multiple sensors is used as a proxy model for expert task performance.*
 - *Experimenting with different methods of automatically defining ‘sub-goals’ from sensor data streams (e.g. Bayesian Nonparametric, shifted peak events, etc.)*
 - *Learn one (or more) reward functions for each partition*
- Provides a measure of the **relative importance of different sensors**
 - *Different weight is given to different sensors, based on the model of expert performance*
- **Less data** required than traditional ‘black box’ approaches
- Modeling reward functions for expert task performance provides a **human-interpretable** explanation of ‘expertise’ which can be used to provide feedback to improve performance
 - *E.g. “Reduce torso movement in the first half of the task”*

PSTAAT Summary

- Supports GIFT vision of streamlining ITS development
 - Help Army achieve its ALM/ALC objectives; more broadly for force-wide readiness
 - Focusing on specific categories of skills (e.g. psychomotor) gives tools more knowledge, power
- PSTAAT provides specialized authoring within GIFT authoring framework
 - Agent-guided workflow, decision support, and contextual examples provide powerful aid
 - Streamlines ITS development with templates, reuse, semi-automation
 - Supports development of simulation-based ITS in the psychomotor domain.
- Novel ML approach to supporting external sensor calibration, skills assessment
- Integration Status
 - Course object integrated
 - Some portions of the GWT editor widgets and panels still in production
 - New psychomotor Unity WebGL training applications nearing completion
 - ML components to be demonstrated but integration into GIFT deferred

Backup Slides

Authoring Tool Sweet-Spot

- ITS Authoring Tools: General-Purpose/Special Purpose Tradeoffs
 - General-purpose tools provide great deal of leeway
 - Tools focused on a specific *kind* of ITS can be more powerful
- PSTAAT: Authoring tool to encapsulate knowledge to guide authoring
 - *Instructional design* knowledge tailored to iteratively teach/practice/assess skills
 - *Psychomotor Domain* knowledge for guiding design decisions and feedback
 - *GIFT ITS* knowledge for authoring, configuration, and sensor application
- Goal: AI-supported authoring for militarily-relevant psychomotor tasks
 - Embody (and help authors adhere to) assumptions about the authored product
 - Enforce rudimentary instructional principles to achieve intended outcomes
 - Streamline ITS development by leveraging templates and semi-automation
 - Provide “sidekick” and “planner” guidance with author-centered support

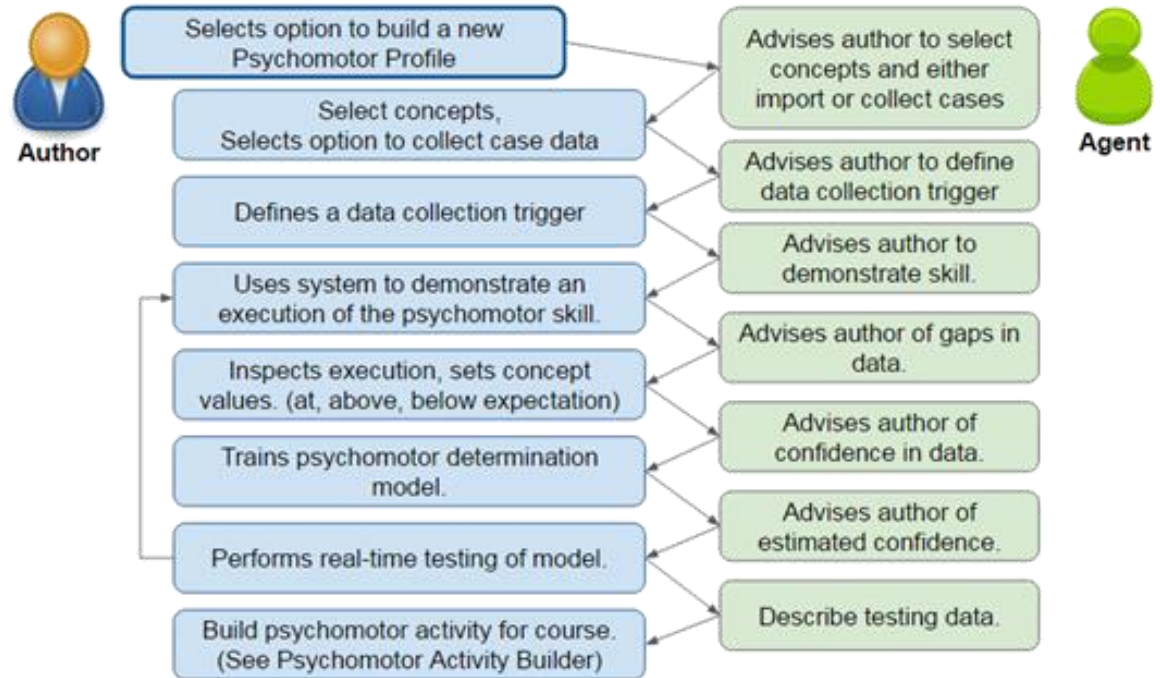
Psychomotor: Making sense of sensors

- Utilize existing and envisioned sensor devices integrated w/GIFT
 - BioHarness
 - Emotiv
 - Kinect
 - Mouse
 - Multisense
 - OS3D
 - Qsensor
 - SineWave



Performance Modeling / ML Model Testing

- System requests demonstration of activity
- Trains ML model using representative cases
- Logic Model for the psychomotor task can:
 - correctly assess future performances
 - make reward-function-based suggestions to improve.



Moving forward

- PSTAAT templates, imports, and exports
 - Authoring agent uses JSON templates to define concepts, instructional approaches, and task workflows
 - PSTAAT tool imports/exports psychomotor profiles, psychomotor activities, *instructional strategies
 - Is this (or similar) templated approach of general interest to other GIFT tools?
- PSTAAT ML-supported features
 - Existing GIFT psychomotor task performance data sources
- Leveraging existing/future GIFT components
 - Reuse is good – harmonization is key
 - Can we embed existing course objects in a psychomotor activity's instructional strategies?
 - Would like more visibility of GIFT Cloud roadmap, related components