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

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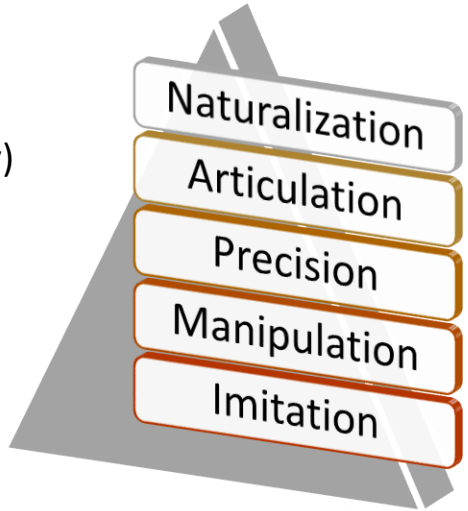
Intelligent Tutoring Challenges

- 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

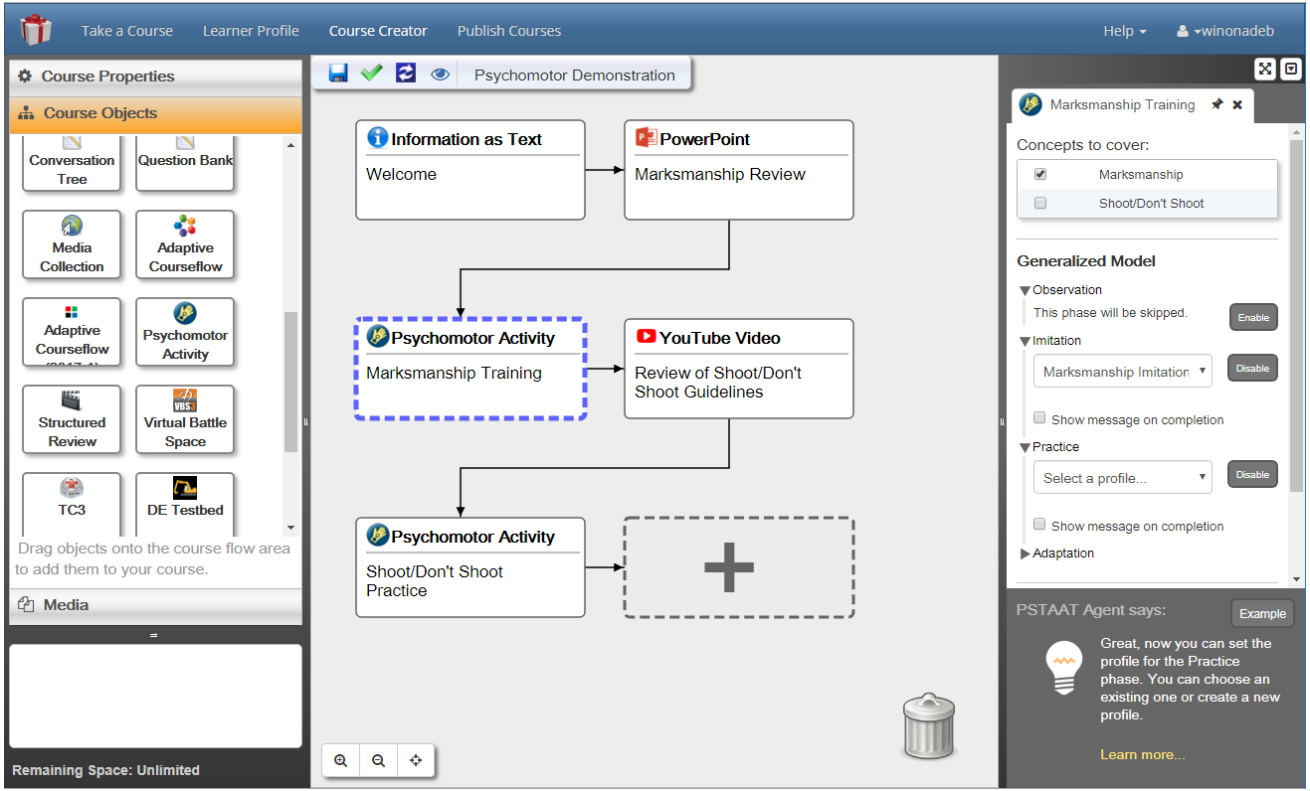
Level	Definition	Example
Observing	Active mental attending of a physical event.	The learner watches a more experienced person. Other mental activity, such as reading may be a part of the observation process.
Imitating	Attempted copying of a physical behavior.	The first steps in learning a skill. The 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

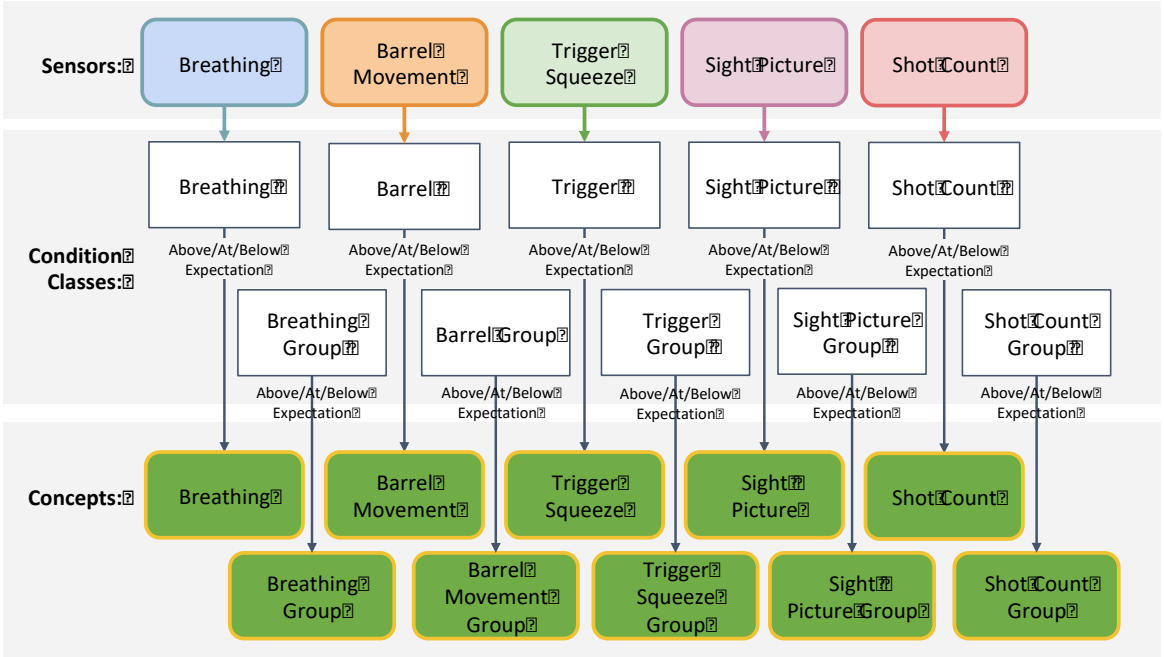
PSTAAT in GIFT



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

Psychomotor: Making sense of sensors

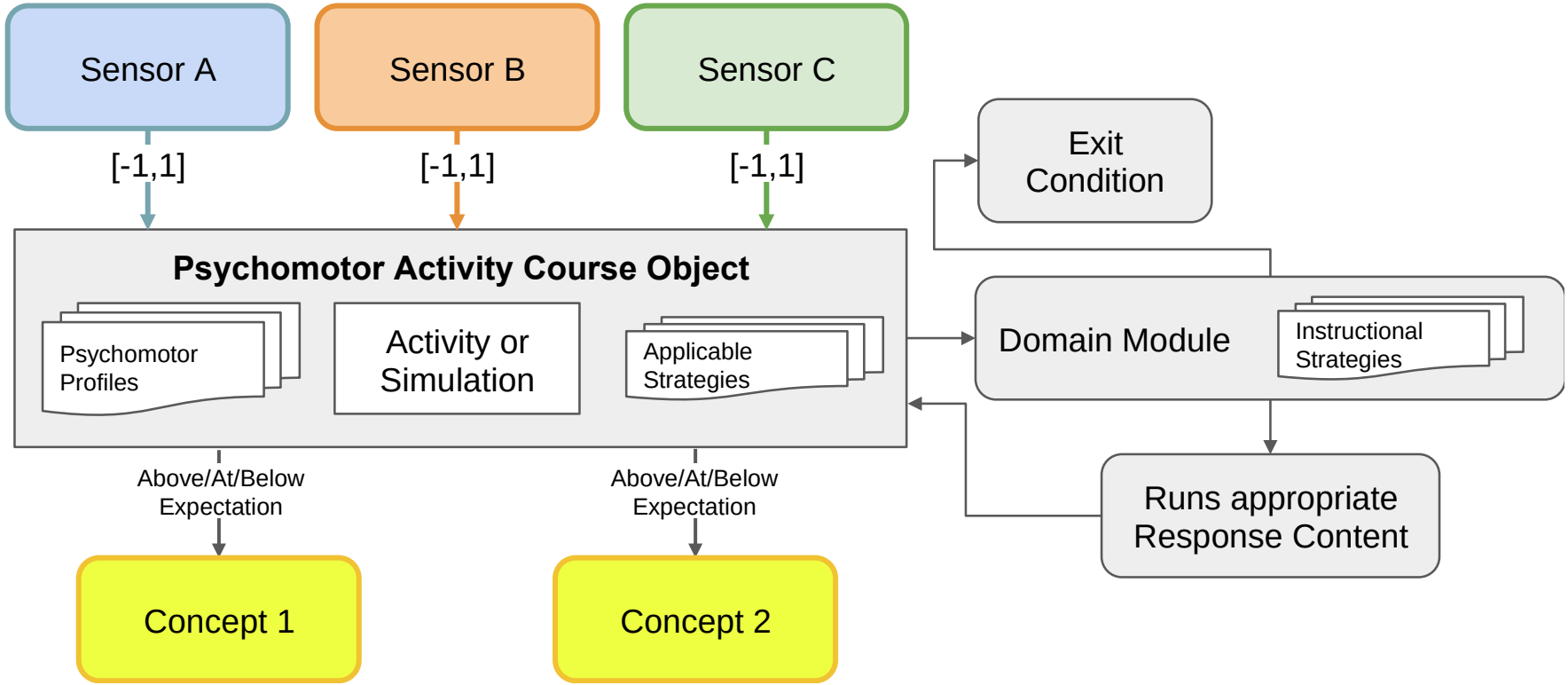
- Separate *sensor configuration* from *instructional design*
- Help author map sensors to concepts
- Generalize approach used in exemplar



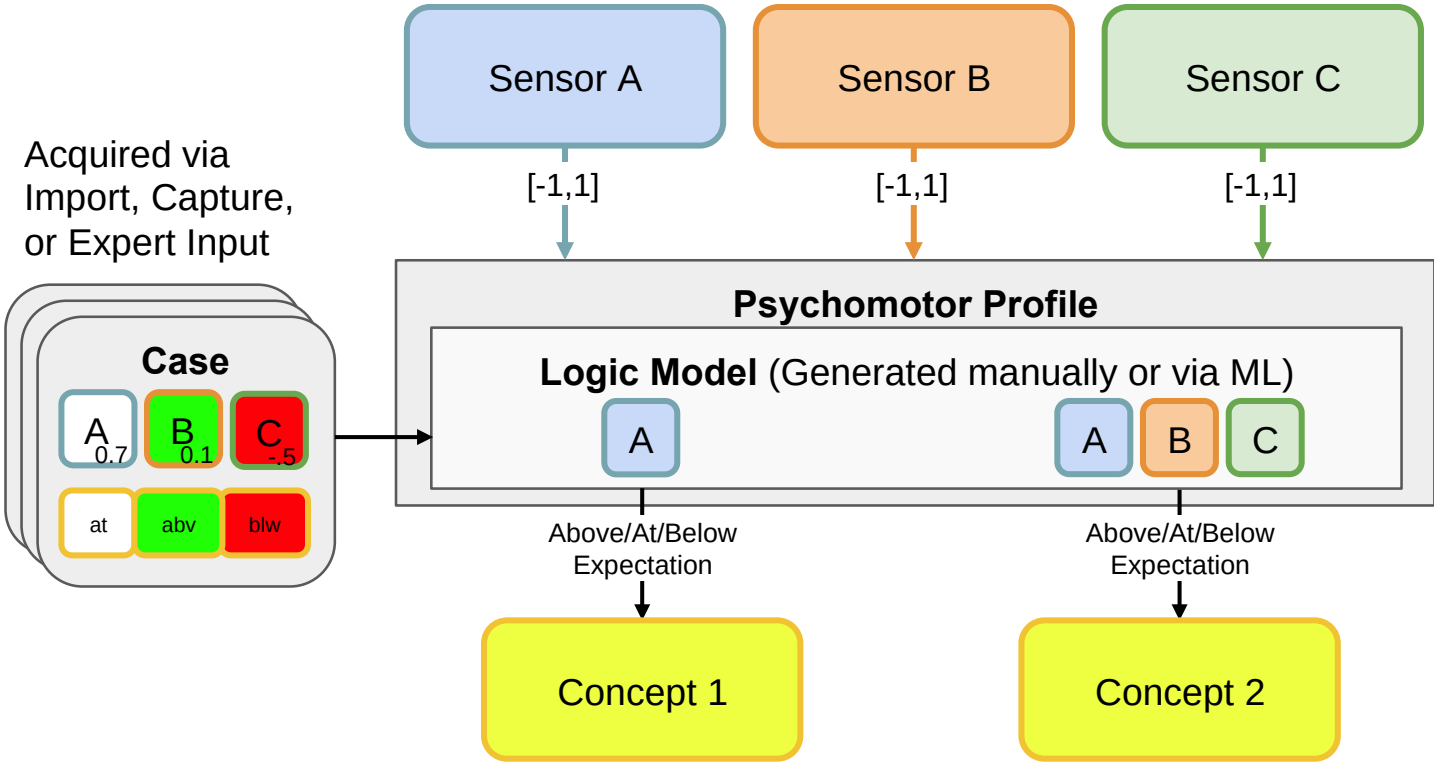
Sensor Configuration:
Psychomotor Profile

Instructional Design:
Psychomotor Activity

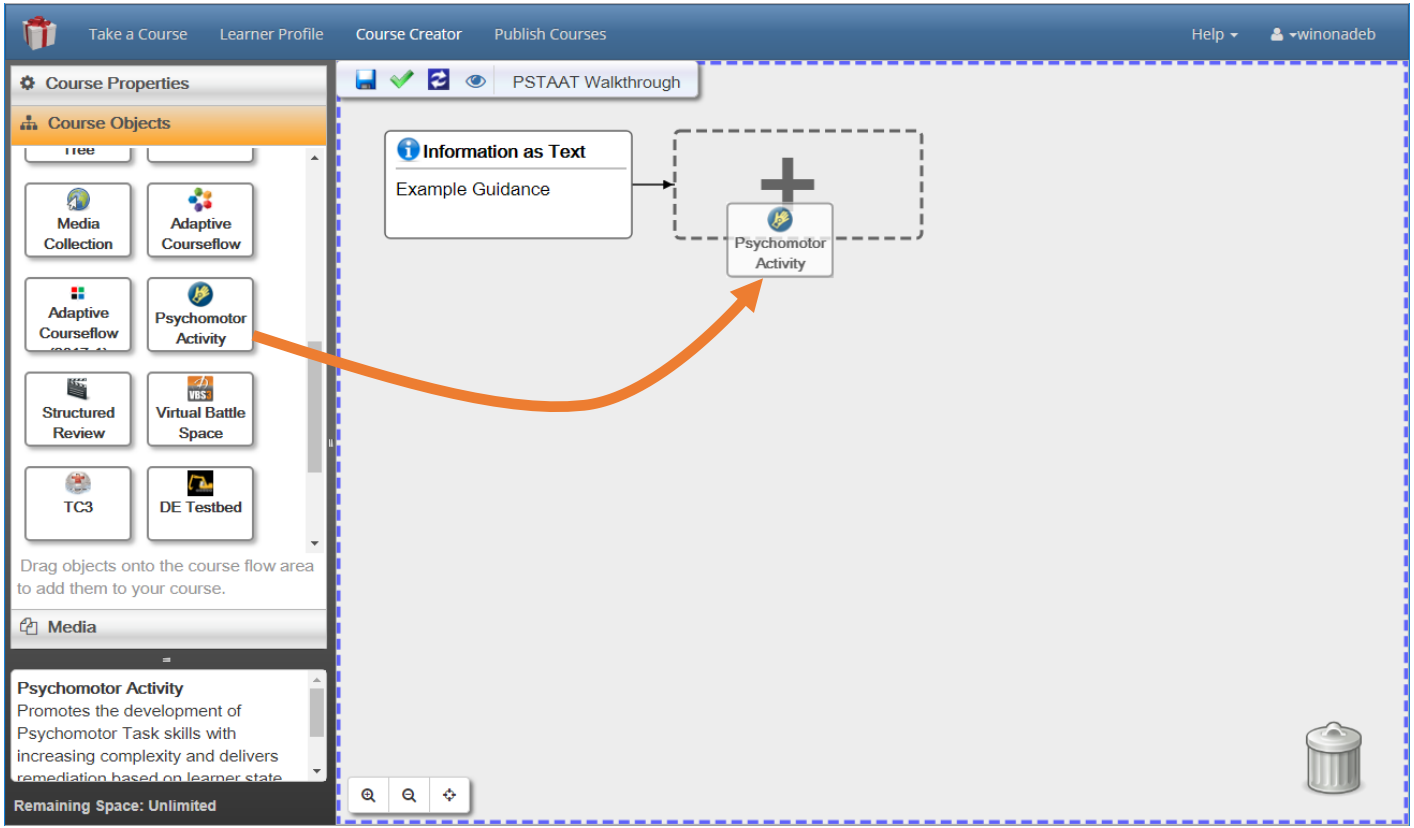
Psychomotor Activity Course Object



Psychomotor Profile



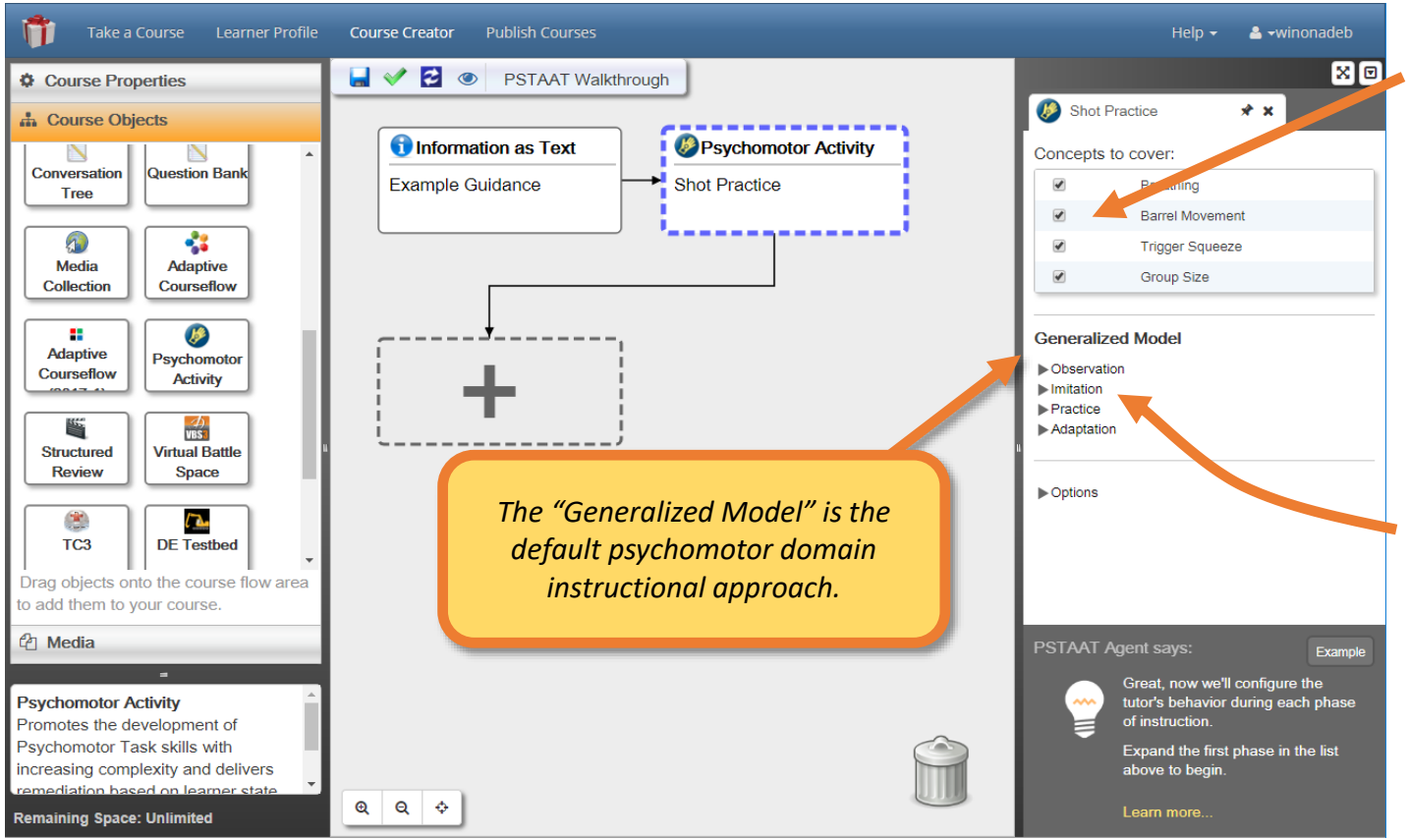
Psychomotor Activity Course Object



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

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

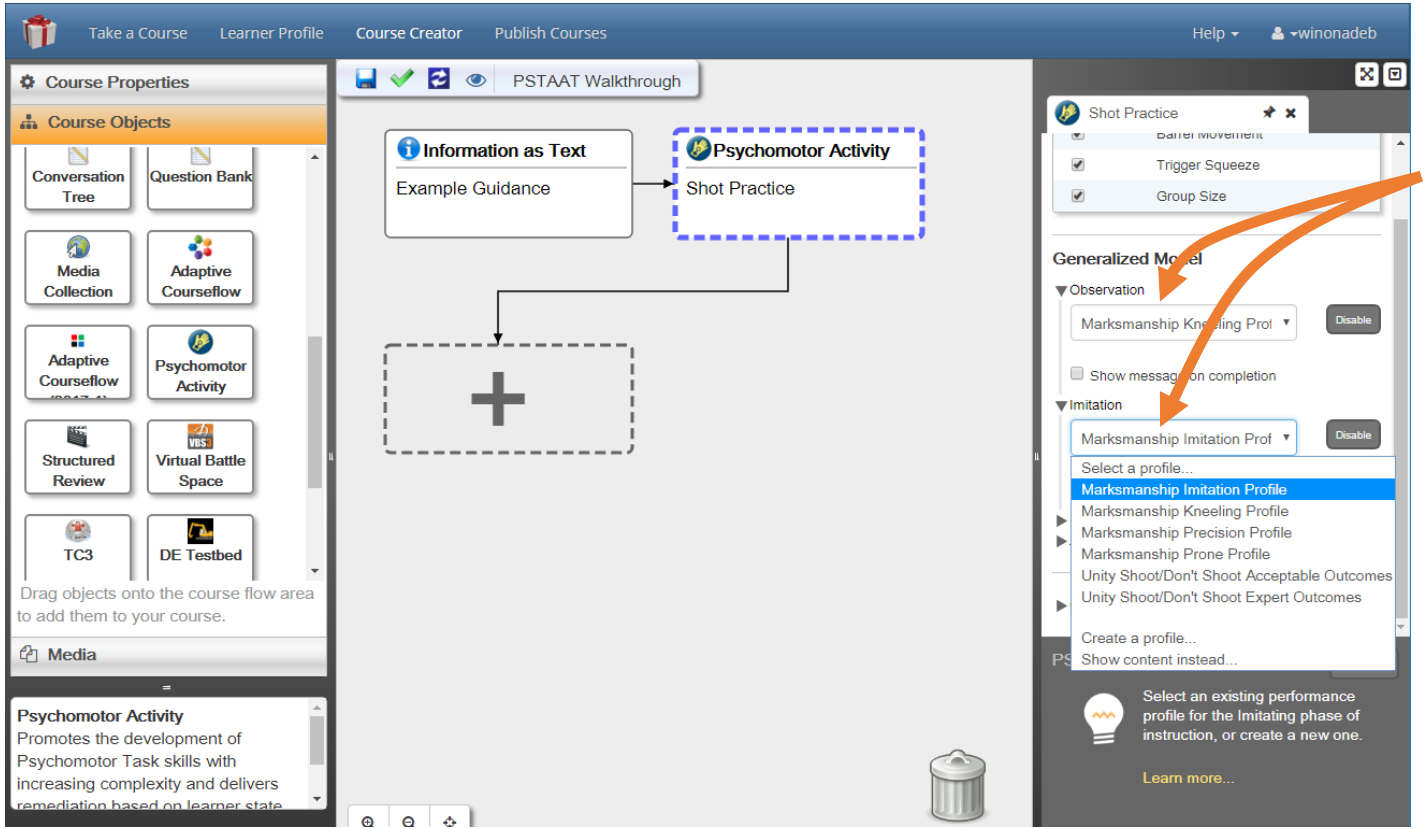
Building the Psychomotor Activity



Author selects concepts and a Psychomotor Domain Instructional Approach.

Agent auto-generates corresponding instructional phases with guidance.

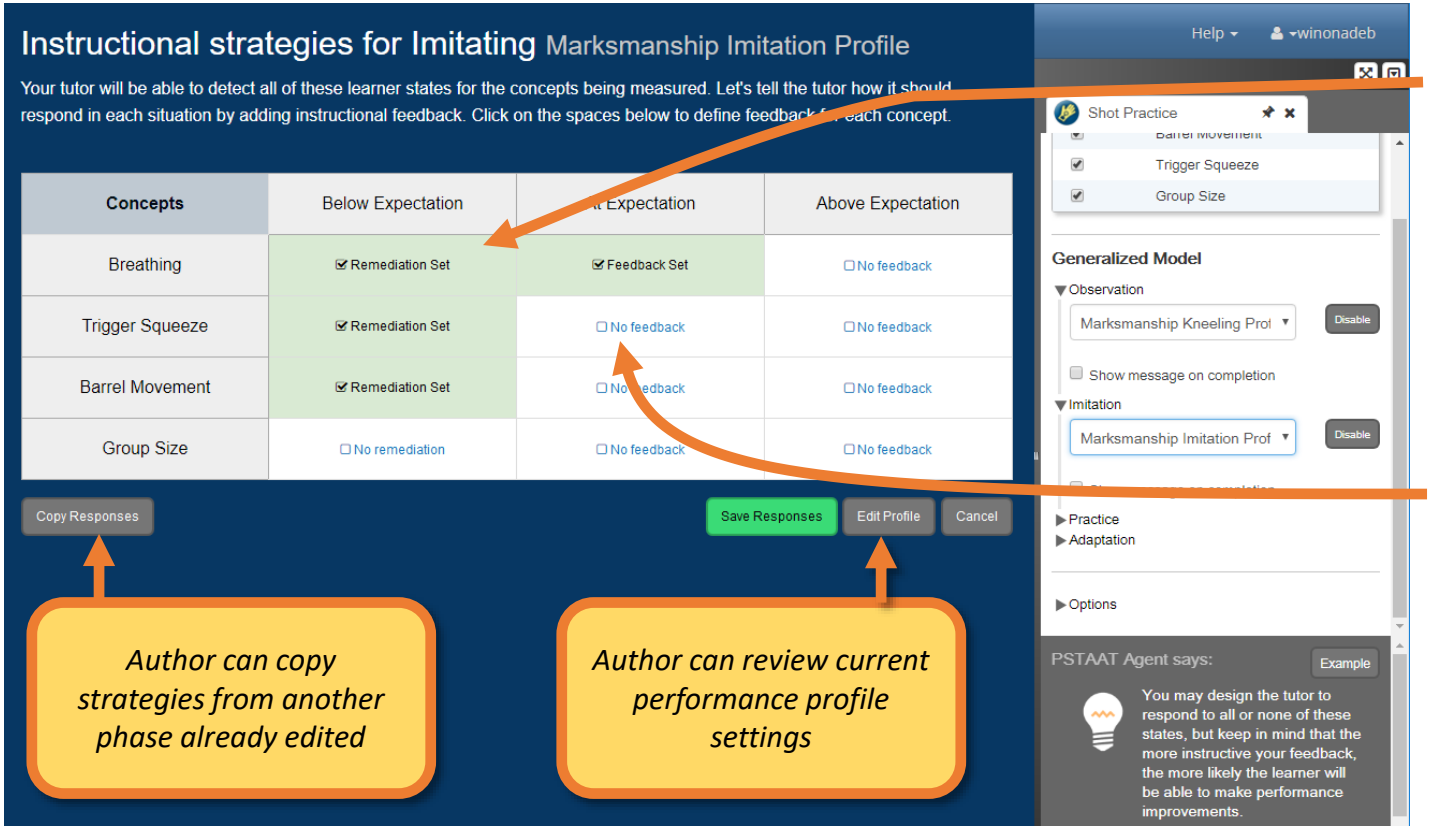
Building the Psychomotor Activity



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.

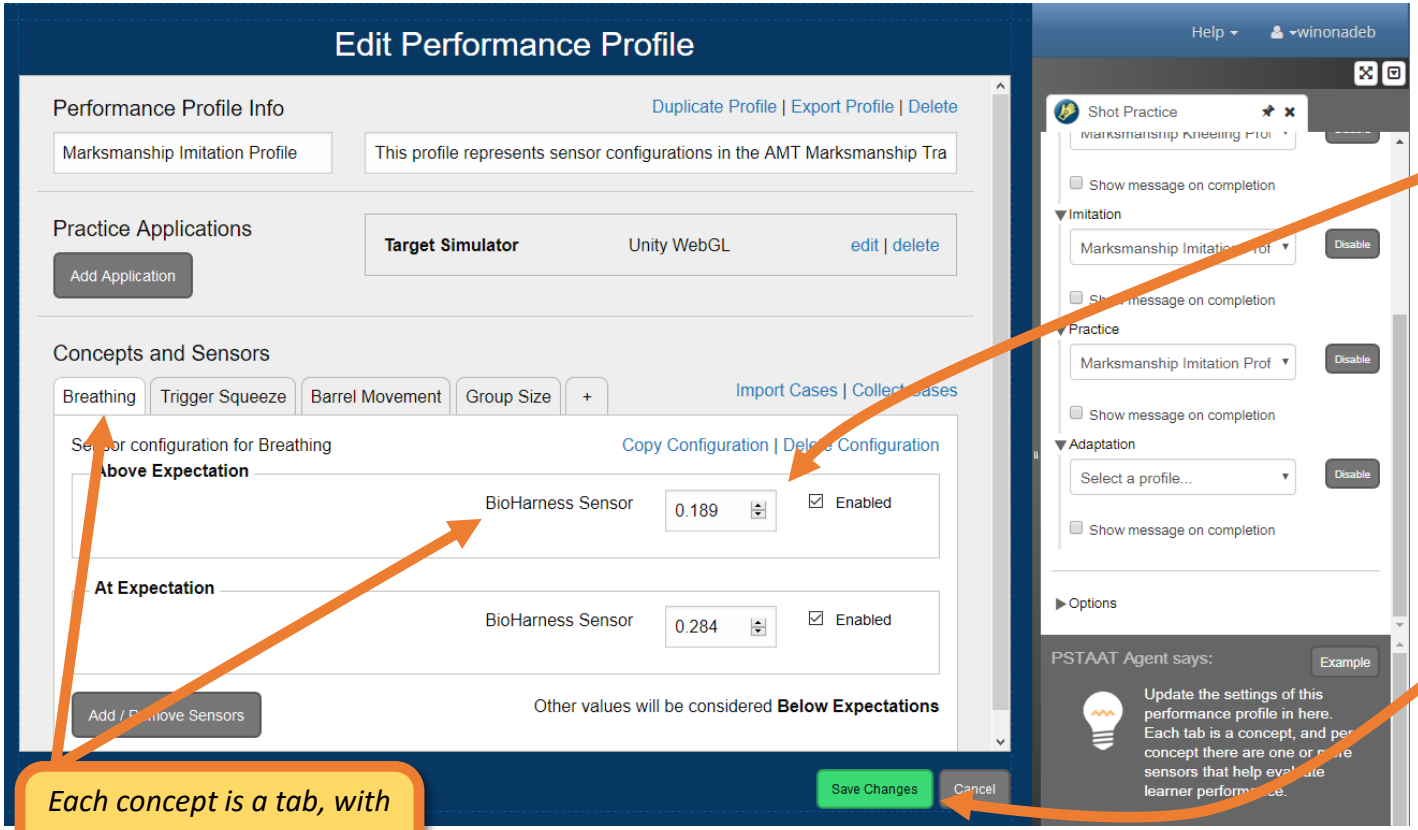
Building the Psychomotor Activity



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

Author designs instructional strategies for each possible performance scenario.

Building the Psychomotor Activity

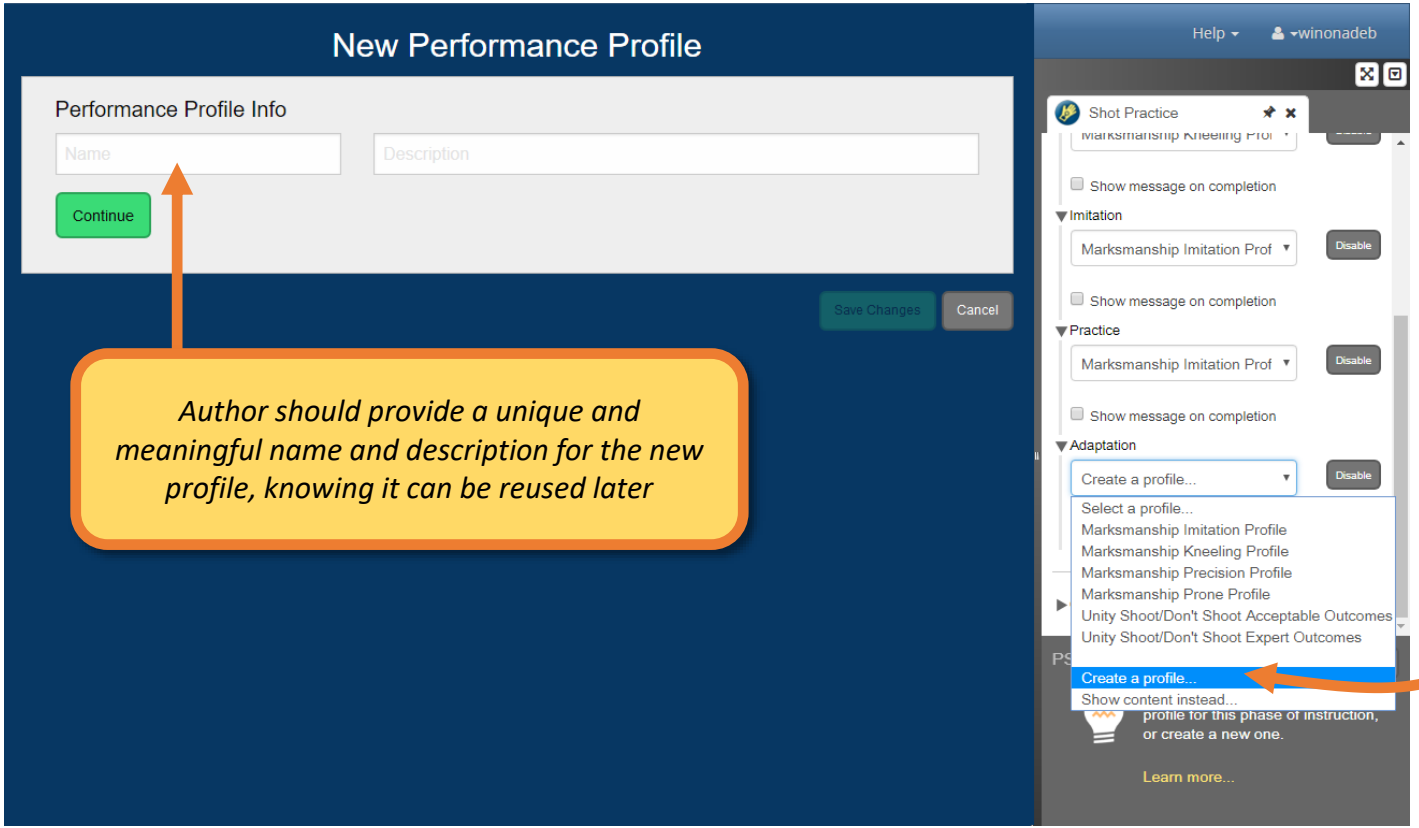


Each concept is a tab, with one or more sensors per concept.

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

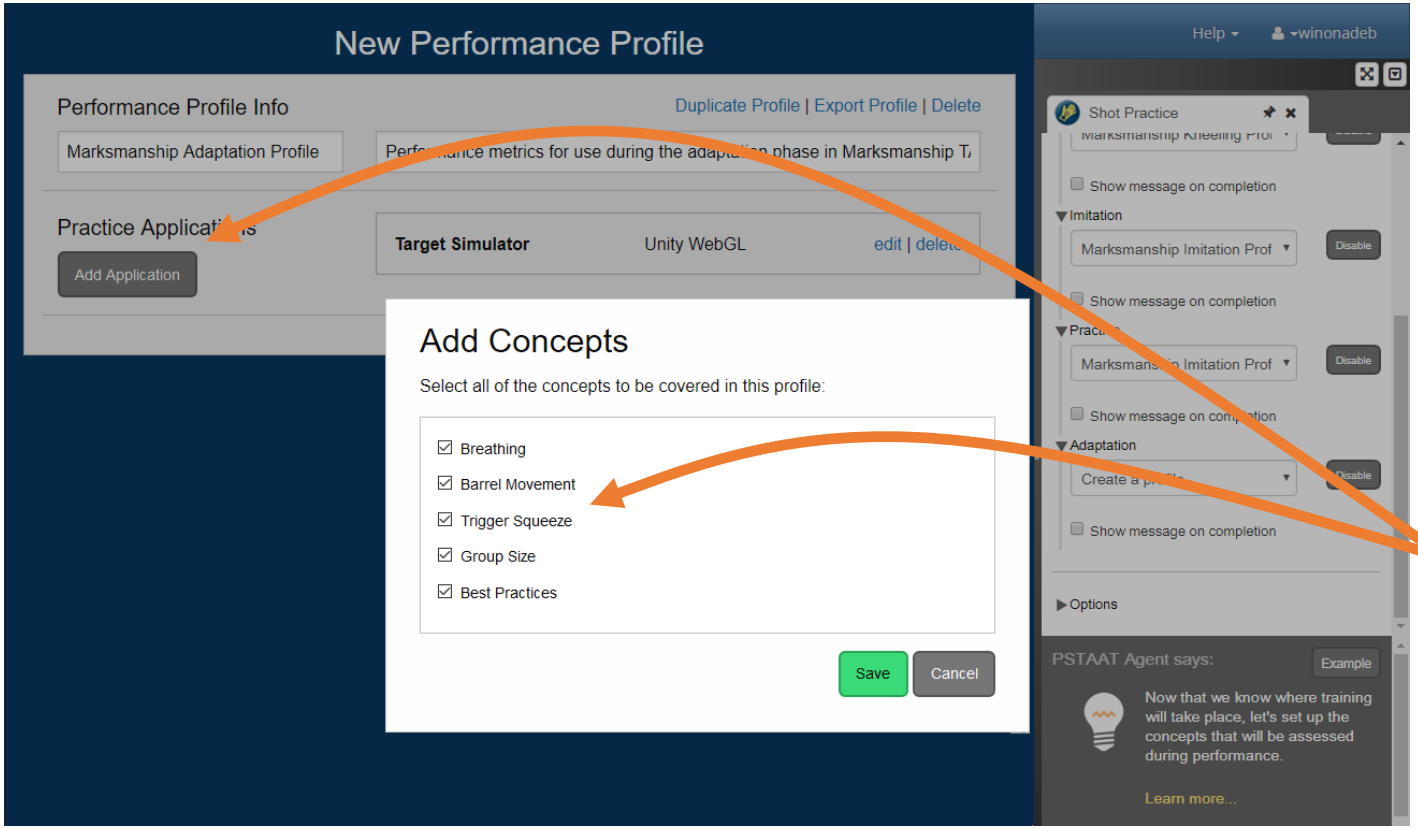
Author can save changes for all uses of the profile, or provide a new name.

Building the Psychomotor Profile



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

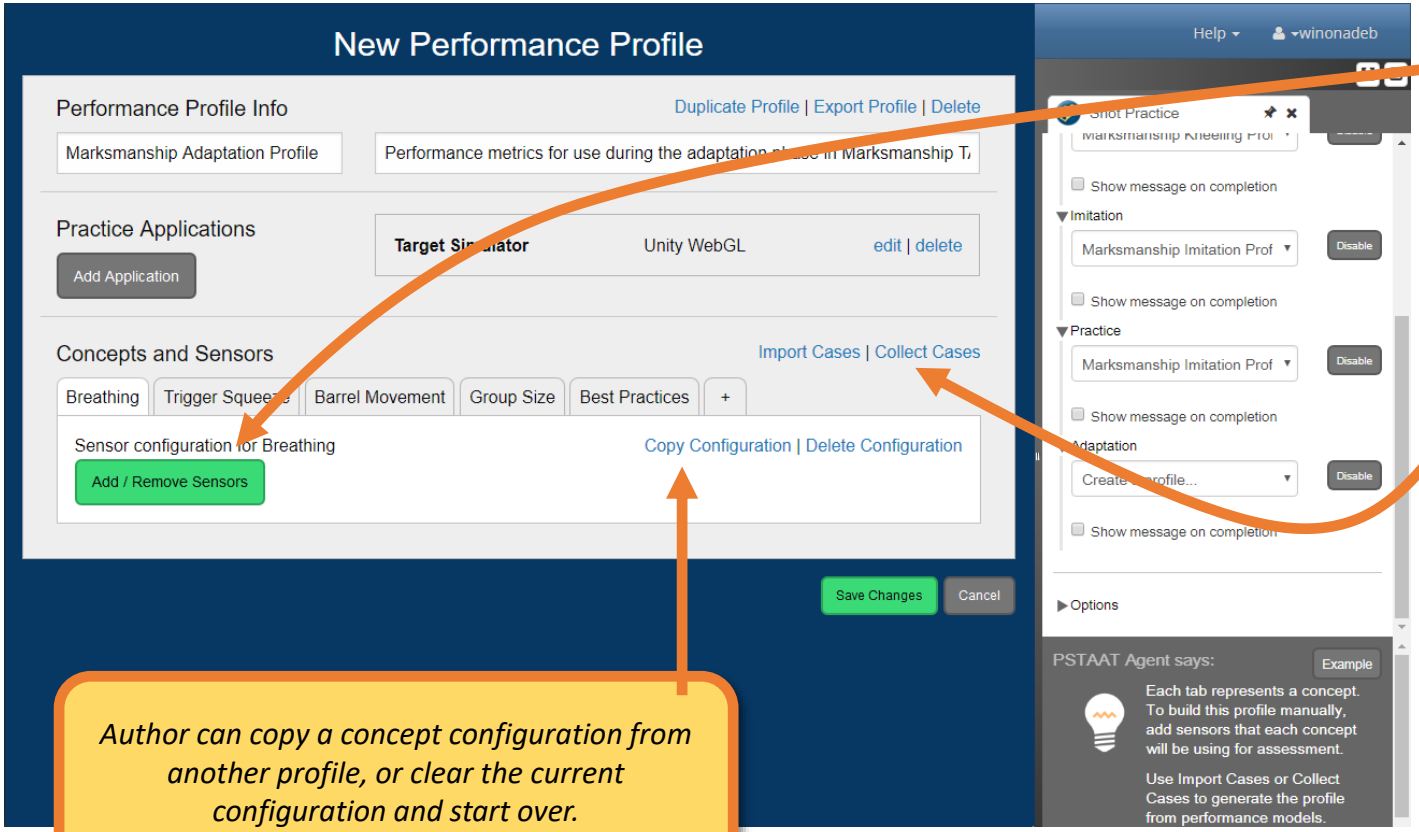
Building the Psychomotor Profile



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.

Building the Psychomotor Profile



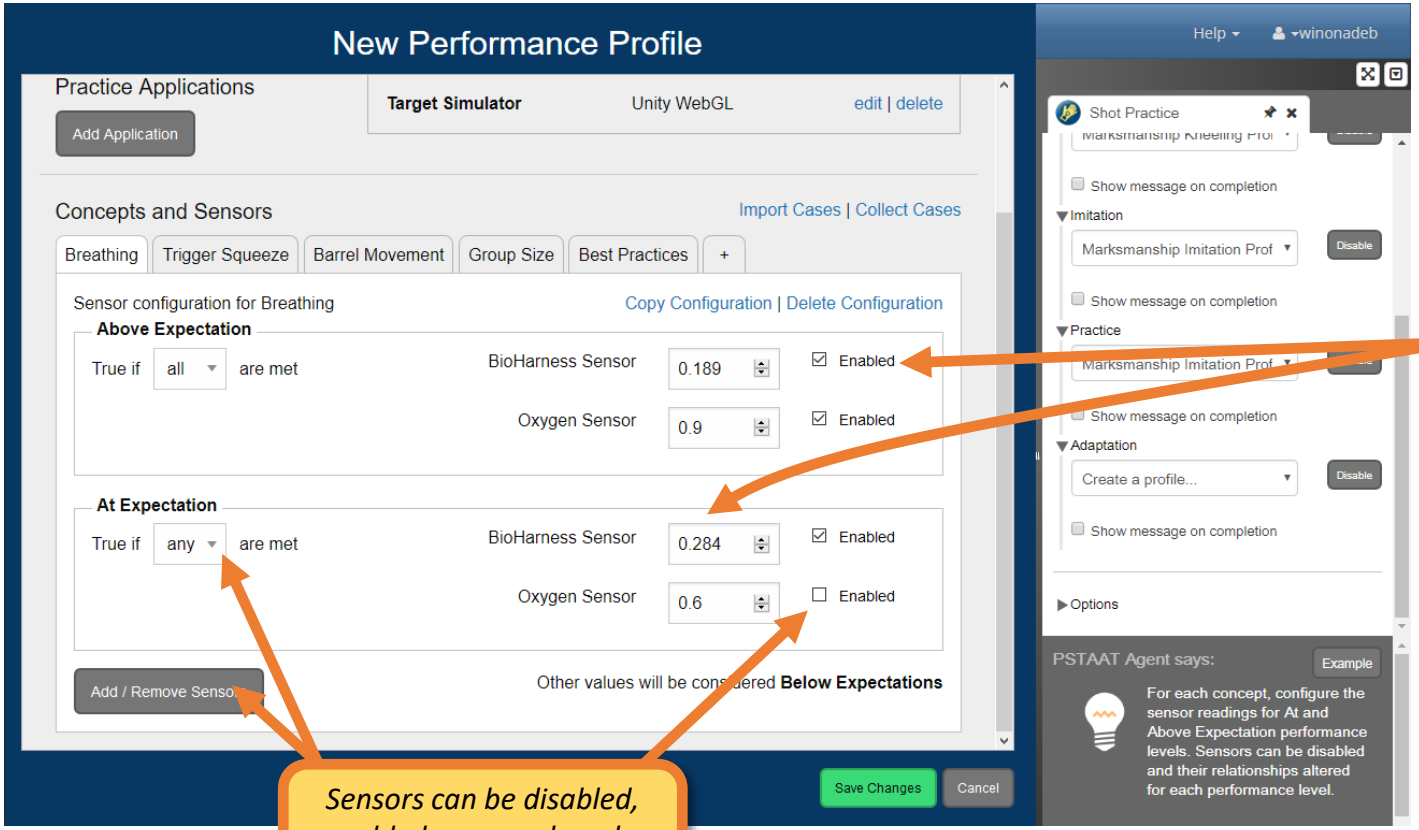
Author can copy a concept configuration from another profile, or clear the current configuration and start over.

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…

Building the Psychomotor Profile



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

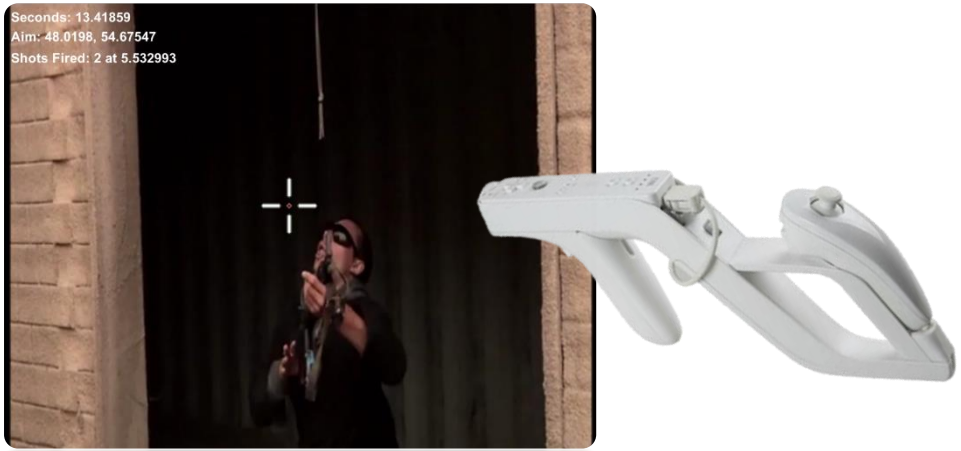
Agent incorporates selected sensor(s) in the concept tab(s).

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

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

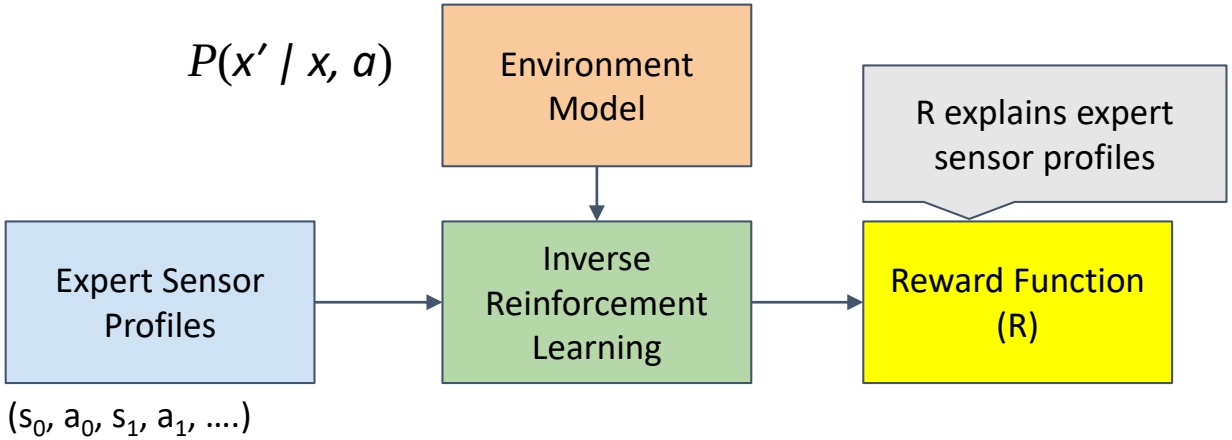


Shoot/Don't Shoot scenario - Psychomotor

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")

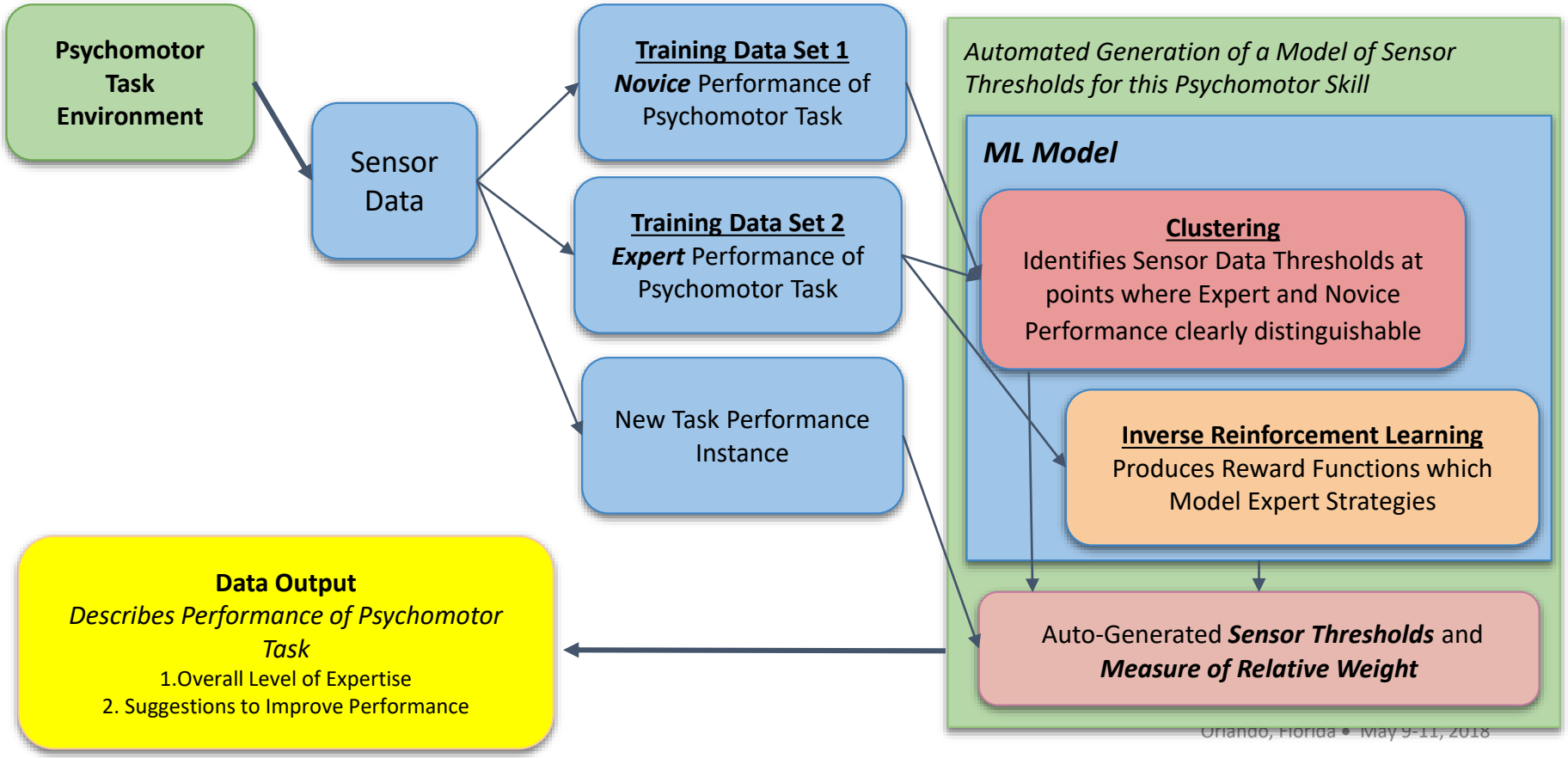
Inverse Reinforcement Learning



Motivation for Inverse RL

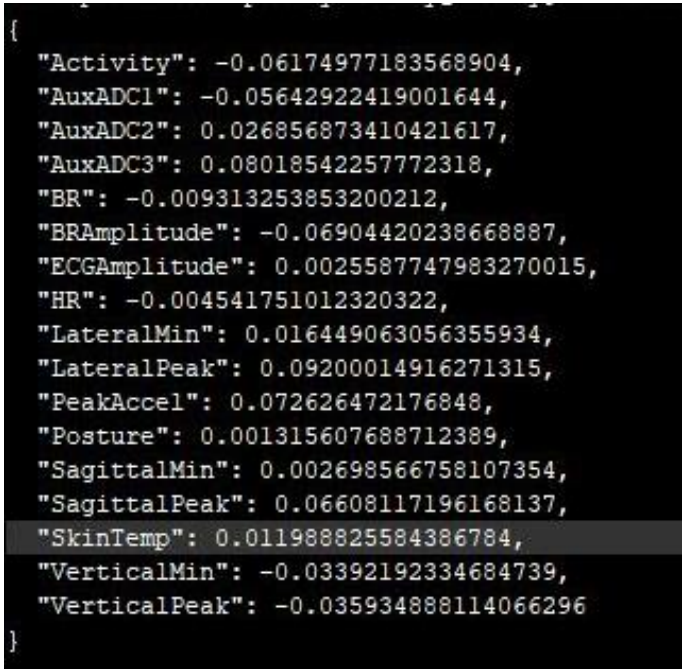
- Apprenticeship Learning through Inverse RL has proven **effective in modeling complex psychomotor task performance** (e.g. bee foraging, songbird vocalization, helicopter flying)
- Reward Function provides both a succinct definition of the task and a **means for providing human-interpretable feedback 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.



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

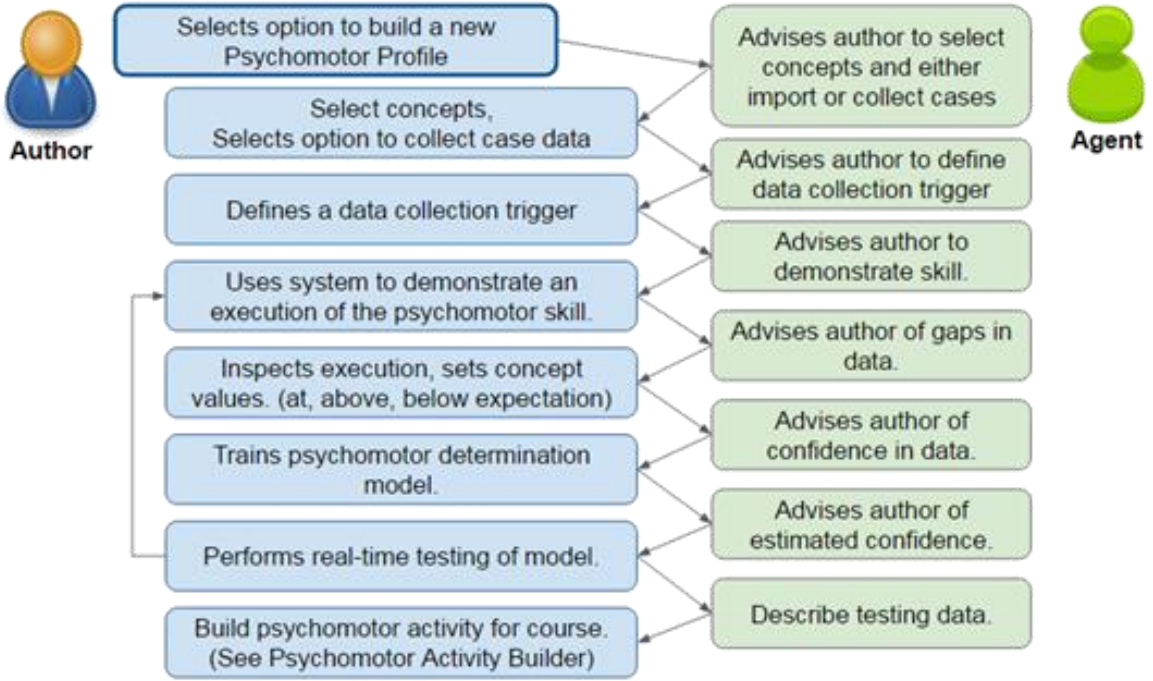
- ITS Authoring Tools: General-Purpose/Special Purpose Tradeoffs
  - General-purpose tools provide great deal of leeway
  - Tools focused on a specific *kind* of ITS can be more powerful
- PSTAAT: Authoring tool to encapsulate knowledge to guide authoring
  - *Instructional design* knowledge tailored 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