A Universal Language and Format to Describe Behavioral Tasks and Data

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MOTIVATION

Technological advances have revolutionized how we measure and manipulate brain activity, while behavioral technologies have lagged behind. Recent developments introduced methods for quantifying movements and poses but we lack general approaches to describe and communicate behavioral tasks, which are necessary to infer internal states not visible from movements alone. Different laboratories use different systems, hardware, and software to probe behavior, making it difficult to communicate task design, share data, or reproduce experiments. Furthermore, neural data archives require matching behavioral data archives for interpreting neural activity. Here we developed a universal framework for designing, implementing, communicating, and archiving behavioral tasks.

APPROACH

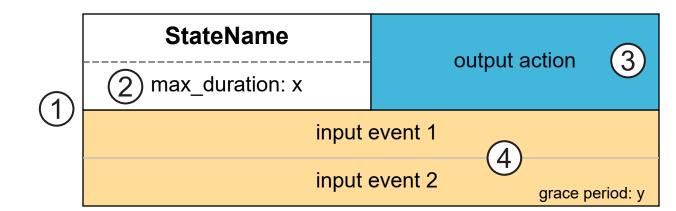
Our framework consists of two components, a description language and a data format along with associated software tools. BEADL, the BEhavioral tAsk Description Language, defines behavioral tasks as virtual finite state machines that can be described graphically as an easy-to-understand flow diagram. In each state, the sensed behavioral output of a subject is defined as events, causing transitions to other states. In addition, each state has a defined list of distinct actions, that the task controlling environment is performing (e.g., stimulus presentation). We use virtual inputs to generalize the descriptive power of this framework. BEADL's graphical representation can be exported as a corresponding XML-based definition. An NWB extension (Neurodata Without Borders) allows for storing of behavioral data capturing both the BEADL task description together with the behavioral output of a subject.

CONCLUSION

- BEADL's graphical representation of task descriptions simplifies designing and communicating trial-based behavioral tasks
- Inherent logic of behavioral tasks is exposed to ensure clarity, precision, details in task designs, communication, and reproducibility
- Web-based BEADL graphical task designer with integrated BEADL-XML generator
- NWB extension to further standardize data formats and to consistently linking neural and behavior data with the contingencies fo the behavioral task
- This standardized framework allows more transparency and reproducibility in behavioral experiments

BEADL Design Workflow BEADL Parser BEADL Design Annotations BEADL Design Environment Experiment Control & Analysis Environment

BEADL Graphical Elements



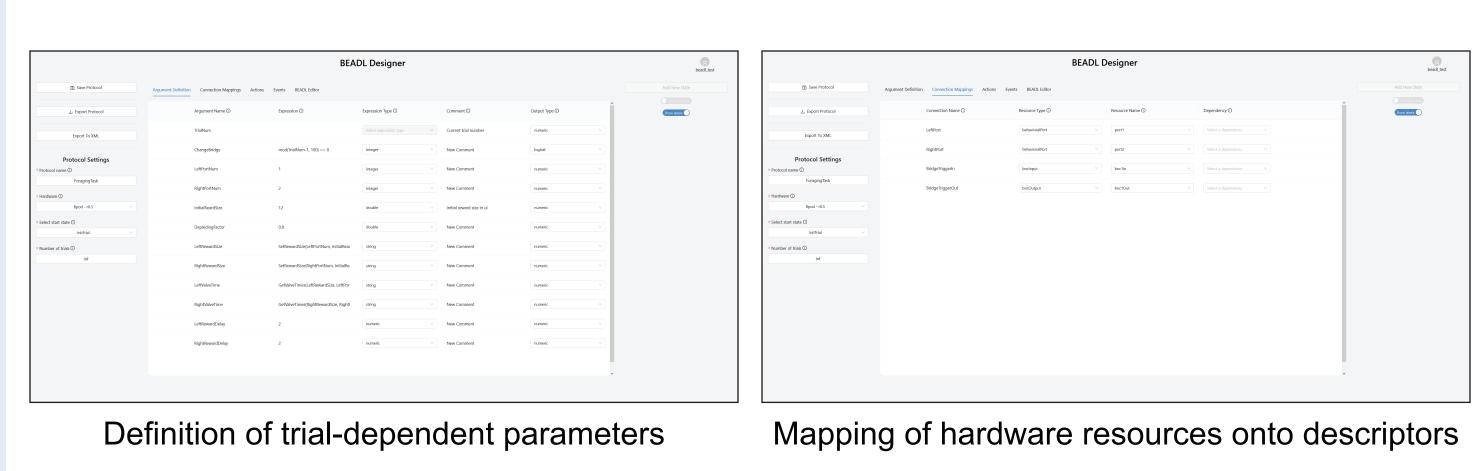
- 1 The default BEADL state definition. Each state has a name, a max. duration, a list of output actions, and a list of input events.
- 2 Each state can have a maximum duration specified in seconds. If it expires, a specific **stateEx-pired** event will be triggered. If the duration is set to infinite (**inf**), this feature is disabled. Trial-dependent parameters can also be used to define the duration of a state.
- In each state, an abritrary number of output actions can be defined that the experiment controlling hardware can perform (e.g. stimulus presentation). Besides those "basic" action, more hardware-oriented advanced actions can also be defined in form of callback functions.
- For each individual state, specific input events can be defined that cause transitions to other states when they occure. Those events can either be inferred by the subject's behavior or by pre-defined conditions (e.g. the maximum state duration).

BEADL Graphical Design Application

- Web application running on Amazon Web Services (AWS)
- Easy-to-use, drag-and-drop graphical editor to define behavioral task as BEADL diagrams
- Individual user workspaces to store different behavioral tasks
- Pre-defined BEADL Use Cases as templates available
- Definition of trial-dependent parameters
- Abstracting control hardware elements, actions, and events through descriptors
- Optional constrains with dependencies to trial-dependent parameters
- Export BEADL-XML description to be used for task executing (currently for Bpod/MATLAB)

BEADL Designer Secretary Proprietable Connection Proprietable Access Based BADL Designer Add House Survey Based Bade BADL Designer Add House Survey Based Bade BADL Designer Protocol Settings Protoco

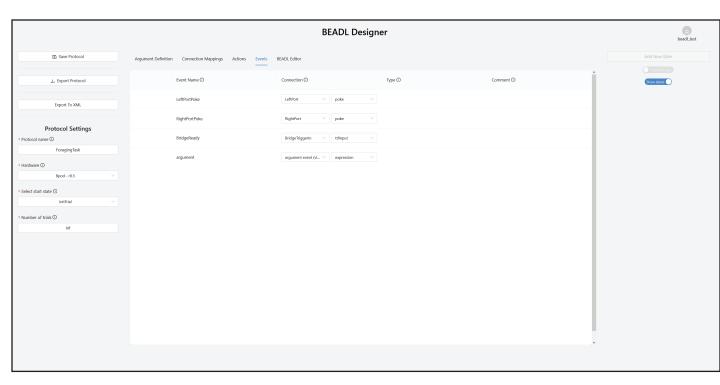
The Foraging Task as a BEADL diagram



Export To XMI.

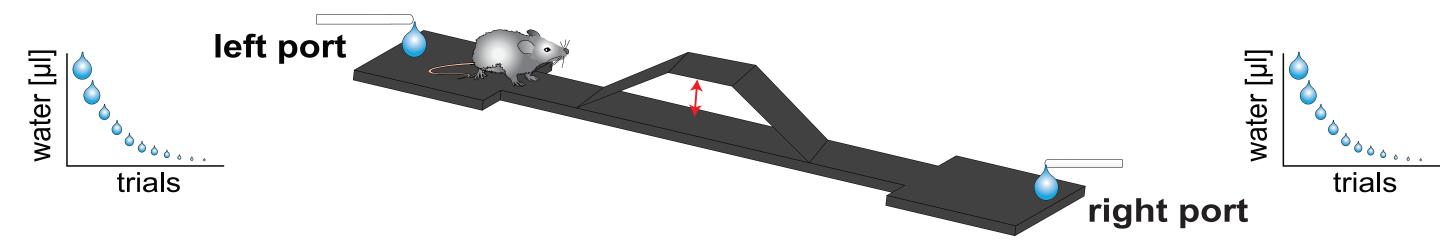
| Protocol Settings | Rejet Protocol name | Rejet

Definition of actions being performed by the task-controlling system during task execution



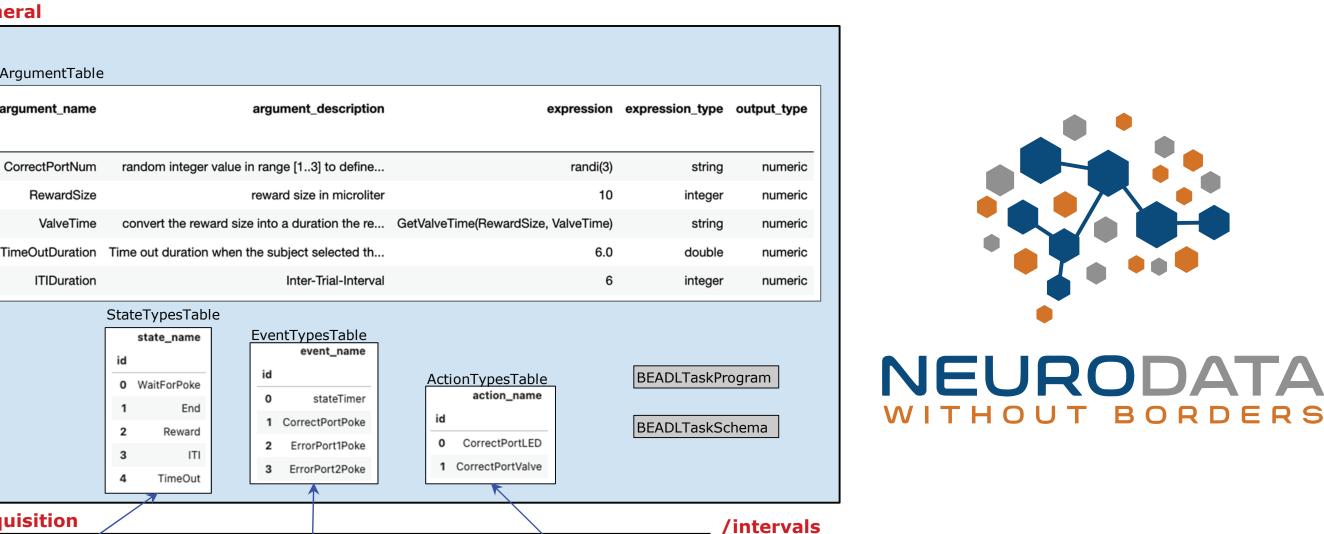
Definition of input events (actions performed by the subject) to trigger state transitions

Example of Abstract Task Representations



A more ambiguous representation of the Foraging Task as cartoon-like figure impeding reproducibility

Neurodata Without Borders (NWB) Extension for BEADL



/acquisition												inter	vals				
StatesTable				EventsTabl	e	ActionsTable					TrialsTable (TimeIntervals)		s)				
	start_time	stop_time	state_type	even	t_type valu	e timestamp	actio	on_type valu	e tim	estamp	Ш	s	tart_time	stop_time	states	events	actions
id				id			id				Ш	id					
0	0.0000	0.2839	0	0	1 0	ut 0.2611	0	0 0	n	0.0000	Ш	0	0.000	6.3409	[0, 1, 2, 3]	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,	[0, 1]
1	0.2839	0.3409	2	1	1	in 0.2839	1	1 ope	en	0.2839	Ш	1	6.422	14.7383	[4, 5, 6, 7]	[67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 7	[2, 3]
2	0.3409	6.3409	3	2	0 expire	ed 0.3409	2	0 0	n	6.4220	Ш	2	14.812	27.0352	[8, 9, 10, 11]	[107, 108, 109, 110, 111, 112, 113, 114, 115,	[4]
3	6.3409	6.3409	1	3	1 0	ut 0.9173	3	1 ope	en	8.6813	Ш	3	27.071	39.0833	[12, 13, 14, 15]	[118, 119, 120, 121, 122, 123, 124, 125, 126,	[5]
4	6.4220	8.6813	0	4	1	in 0.9198	4	0 0	n	4.8120	Ш	4	39.143	46.8732	[16, 17, 18, 19]	[128, 129, 130, 131, 132, 133, 134, 135, 136,	[6, 7]
											Ш			***			

- NWB extension stores BEADL task XML and schema alongside behavioral data associated with trials, states, and events in an NWB file
- Python API provides functions for importing Bpod data corresponding to a BEADL task description and querying the BEADL state/event definition from a recorded state/event

Resources

Please visit <u>beadl.org</u> for additional information, documentation, and upcoming features!



