Learning to Interpret Natural Language Commands through Human-Robot Dialog

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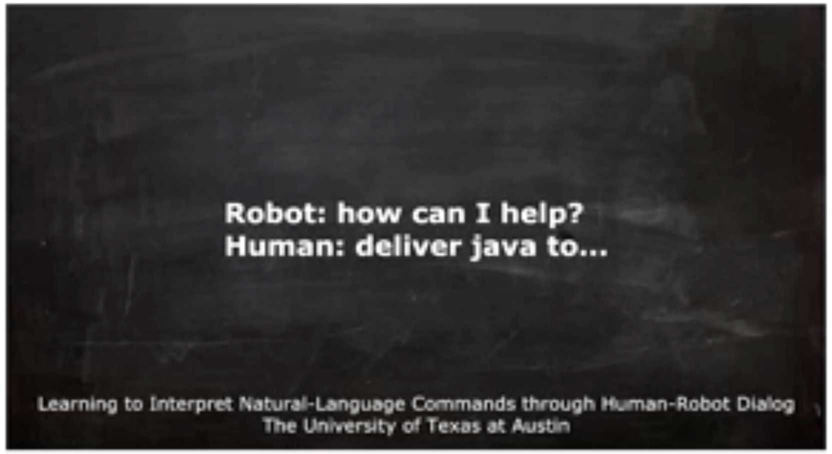
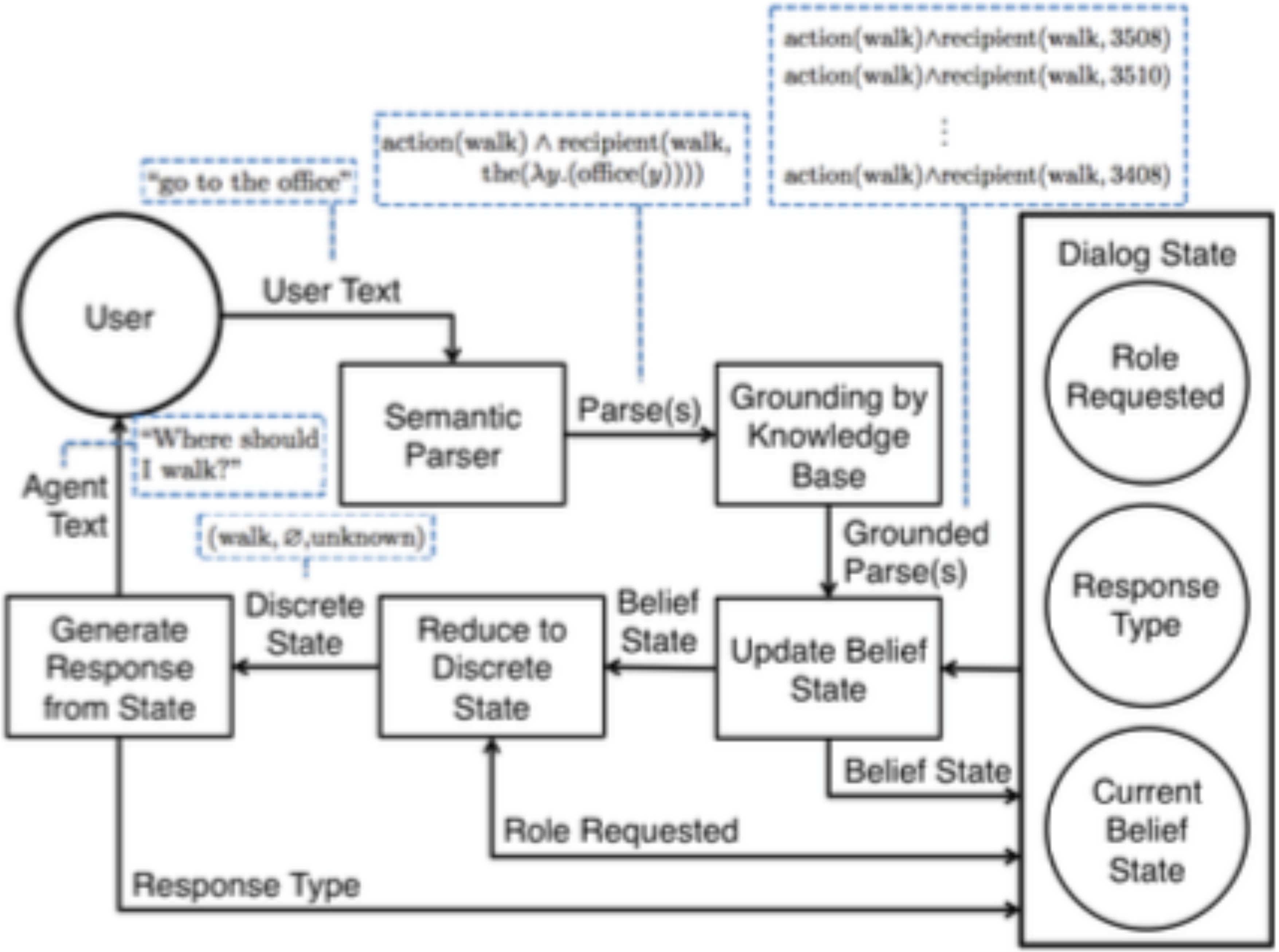
Task

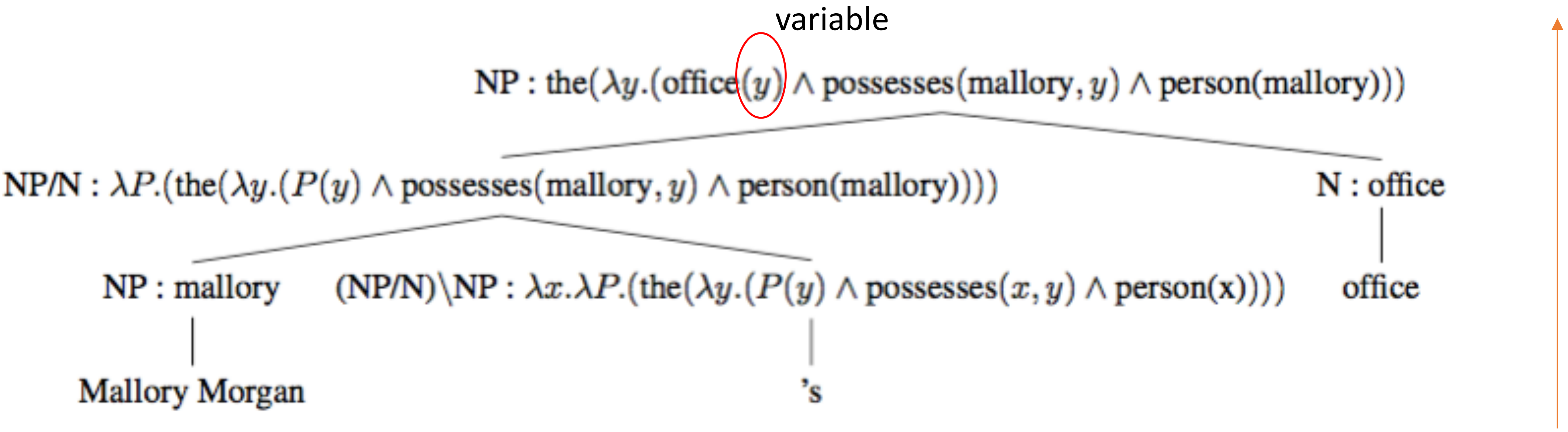
Develop a dialog agent for mobile robots understanding human instructions through semantic parsing




"go to the office"
action(walk) ∧ recipient(walk, the(λy.(office(y))))
action(walk)∧recipient(walk, 3508)
action(walk)∧recipient(walk, 3510)
action(walk)∧recipient(walk, 3408)
User
User Text
Semantic Parser
Parse(s)
Grounding by Knowledge Base
Grounded Parse(s)
Dialog State
Role Requested
Response Type
Current Belief State
"Where should I walk?"
Agent Text
(walk, ∅, unknown)
Discrete State
Belief State
Generate Response from State
Reduce to Discrete State
Update Belief State
Belief State
Role Requested
Response Type

Semantic parser

- λ – calculus
- Combinatory categorical grammar (CCG)



Mallory Morgan's office

NP: Noun phrase
N: Noun

Belief state

- Three components:
  - Each component is a histogram of confidences over possible assignments
  - Action: walking and bringing items -> [0,1]
  - Recipient -> (people, room, items) U null
  - Patient -> (people, room, items) U null

Multiple meaning hypotheses:

Expression: go to the office
Logical form: action(walk) ^ recipient(walk, the $(\lambda y.office(y))))$

Updating the Belief state

- For open-ended statement (update all hypotheses):

$$conf\left(c = H_{i,c}\right) \leftarrow conf\left(c = H_{i,c}\right)\left(1 - \frac{\alpha}{k}\right) + \frac{\alpha}{k}$$

α – threadhold of confidence

- For unmentioned arguments:

$$conf\left(c = \overline{H_{j}}_{,c}\right) \leftarrow \gamma conf\left(c = \overline{H_{j}}_{,c}\right)$$

γ – decay parameter

Responding

Reduce to discrete state:

$$T_c = argmax_{t \in A_c}(conf(c = t))$$

T_c- the top candidate arguments

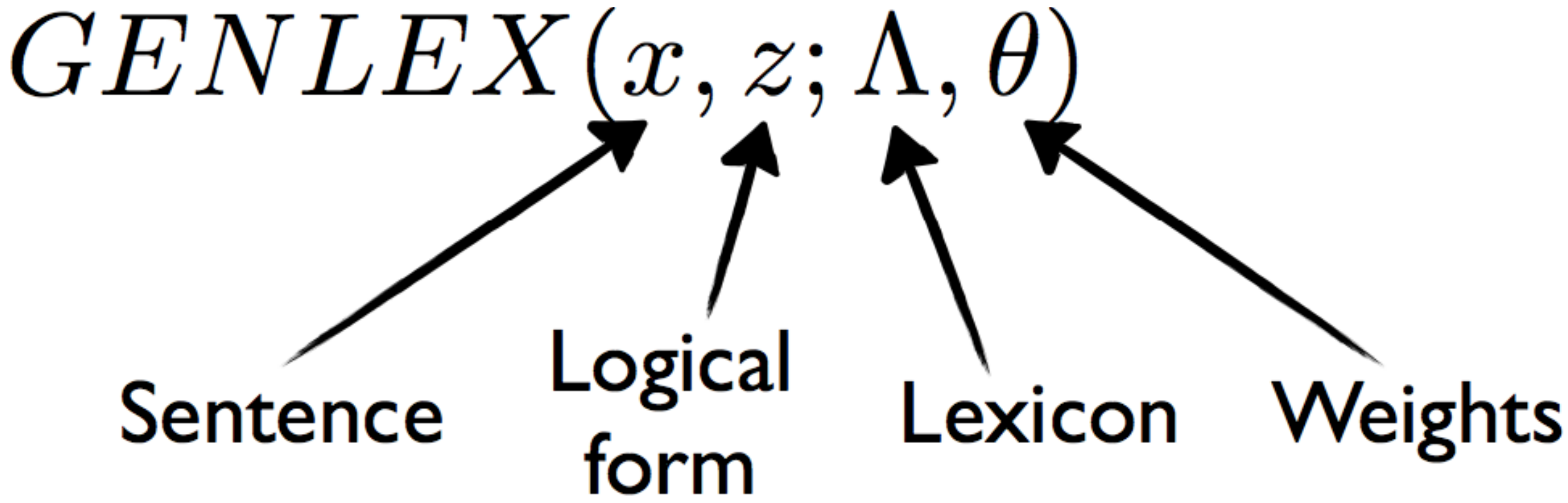
Table 1: Representative subset of our policy π for mapping discrete states S' to actions (questions to ask the user).

S'		$\pi(S')$	
(action,patient,recipient)	**Role Request**	**Text**	**Initiative**
(unknown,unknown,unknown)	all	Sorry I couldn't understand that. Could you reword your original request?	user
(unknown,$T_{\texttt{patient}}$,$T_{\texttt{recipient}}$)	action	What action did you want me to take involving $T_{\texttt{patient}}$ and $T_{\texttt{recipient}}$?	system
(walk, ∅,unknown)	recipient	Where should I walk?	system
(bring,unknown,$T_{\texttt{recipient}}$)	patient	What should I bring to $T_{\texttt{recipient}}$?	system
(walk, ∅, $T_{\texttt{recipient}}$)	confirmation	You want me to walk to $T_{\texttt{recipient}}$?	system
(bring, $T_{\texttt{patient}}$, $T_{\texttt{recipient}}$)	confirmation	You want me to bring $T_{\texttt{patient}}$ to $T_{\texttt{recipient}}$?	system

Learning from conversations

Template-based lexical generation procedure (GENLEX)

- For each utterance paired with a logical form seen during training:



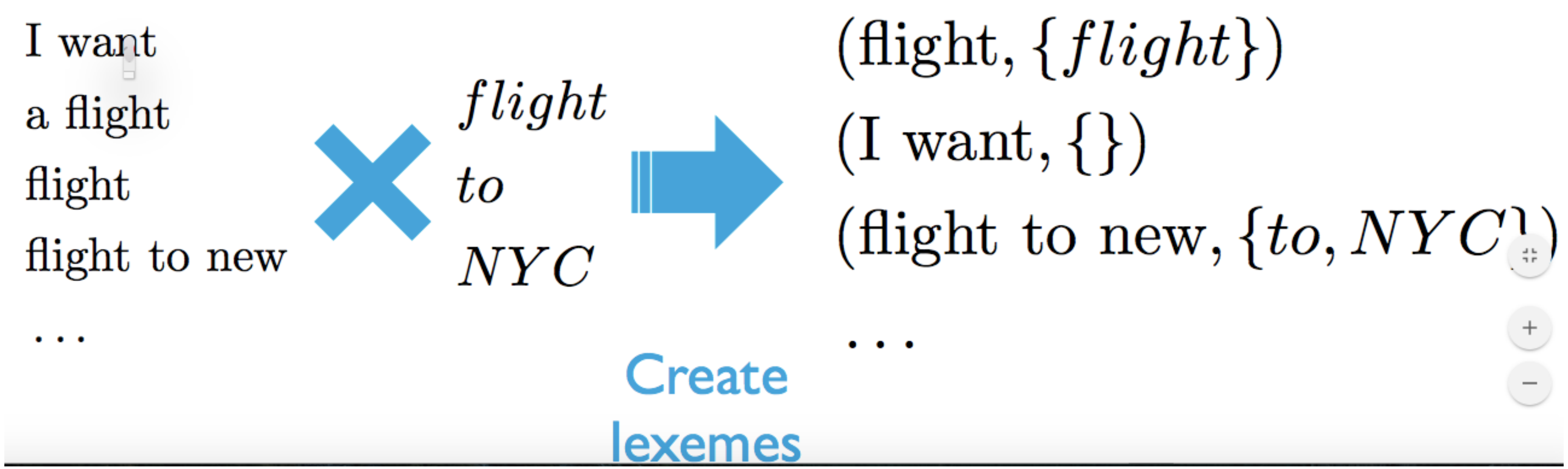
Learning from conversations

Template-based lexical generation procedure (GENLEX)

- For each utterance paired with a logical form seen during training:

I want a flight to New York.

$$\lambda x.flight(x) \wedge to(x, NYC)$$



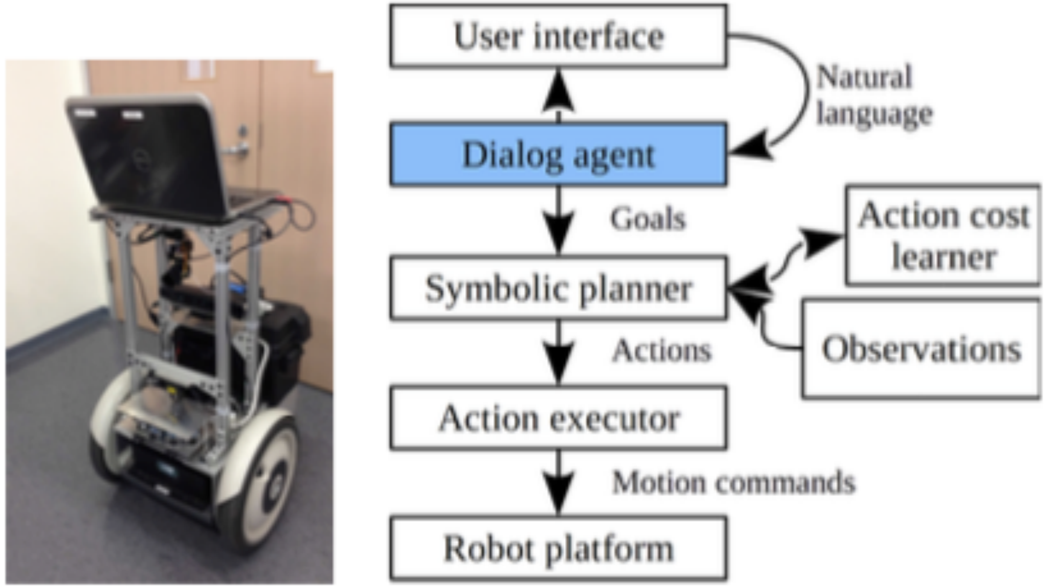
Experimental setup

- Mechanical Turk
- Segbot Experiment
- Task:
  - Navigation
  - Delivery
- Survey

ROBOT	How can I help?
YOU	please bring the item in slot 5 to dave daniel
ROBOT	To whom should I bring something?
YOU	dave daniel
ROBOT	What action did you want me to take involving dave daniel?
YOU	5
ROBOT	What should I bring to dave daniel?
YOU	a calander
ROBOT	I'm sorry, but I couldn't pinpoint what you meant by that.
ROBOT	What should I bring to dave daniel?
YOU	a day planner
ROBOT	I'm sorry, but I couldn't pinpoint what you meant by that.
ROBOT	What should I bring to dave daniel?
YOU	calendar
ROBOT	You want me to bring calendar to dave daniel?
YOU	yes
ROBOT	I thought so
ROBOT	Happy to help
YOU	

Final Task

Mechanical Turk



Segbot

Result (Mechanical turk)

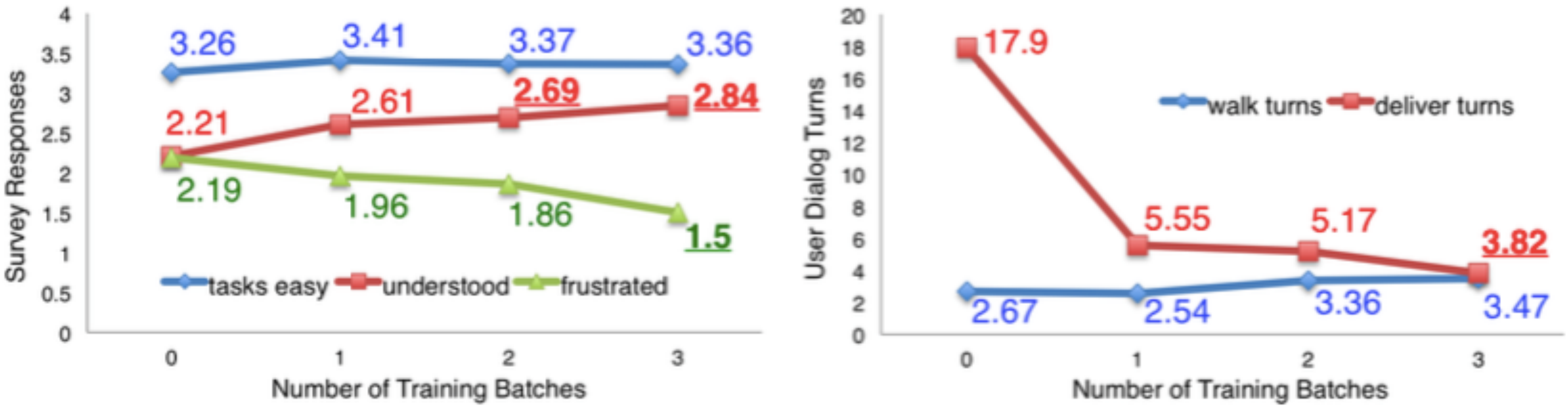


Figure 4: **Left**: Average Mechanical Turk survey responses across the four test batches. **Right**: Mean user turns in Mechanical Turk dialogs where the correct goal was reached. Means in underlined bold differ significantly ($p < 0.05$) from the batch 0 mean.

Result (Segbot)

Table 2: Average Segbot survey responses from the two test groups and the proportion of task goals completed. Means in bold differ significantly ($p < 0.05$). Means in italics trend different ($p < 0.1$).

	Init Test	Trained Test
Survey Question	Likert [0-4]	
Tasks Easy	3.8	3.7
Robot Understood	1.6	**2.9**
Robot Frustrated	2.5	*1.5*
Use Navigation	2.8	2.5
Use Delivery	1.6	2.5
Goals Completed	Percent	
Navigation	90	90
Delivery	20	*60*