Contents


```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Main Simulation Script for BoundingOverwatch Project with R Integration
% Randomly 10 trials is used to validate predictions
% DFT Parameters:
% phi1 - sensitivity to attribute differences (typically 0.5-2)
% phi2 - memory/feedback strength (0-1)
% tau - decision time steps (integer > 0)
% error_sd - noise standard deviation (σ_ε)
% beta - attribute weights from R estimation
% w -  attention weights (default [0.5;0.5])
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc;
clear all;
```

Step 1: Import CSV Data

(reference apolloMain_5 amd apolloMain_6 as example for data manipulation) biasData = readtable('user_choices.csv'); % Replace with the path to your data file disp('User bias data imported successfully.'); taskChoice_Data = readtable('user_choices.csv'); % Replace with the path to your data file disp('User task choice data imported successfully.');

```
robotChoice_Data = readtable('G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\data\Bounding_Overwatch_Data\HumanData_Bounding_Overwatch - 20Split.csv'
% Convert all column headers to lowercase
robotChoice_Data.Properties.VariableNames = lower(robotChoice_Data.Properties.VariableNames);
disp('User robot choice data imported successfully.');

% Randomly select 10 rows (or all rows if fewer than 10)
numRows = height(robotChoice_Data);
randomIndices = randperm(numRows, min(10, numRows));
robotChoice_Data = robotChoice_Data(randomIndices, :);

% Extract robot state attributes dynamically
robot_states = struct();
attributeSuffixes = {'traversability', 'visibility'}; % No leading underscores
for i = 1:3
    for attr = attributeSuffixes
        csvColName = sprintf('robot%d_%s', i, attr{1});  % Matches CSV column names
        structFieldName = attr{1};  % Valid field name
        if ismember(csvColName, robotChoice_Data.Properties.VariableNames)
            robot_states.(['robot' num2str(i)]).(structFieldName) = robotChoice_Data.(csvColName);
        else
            warning('Missing attribute column: %s', csvColName);
            robot_states.(['robot' num2str(i)]).(structFieldName) = NaN(height(robotChoice_Data), 1);
        end
    end
end

% Extract choice data and other metadata
choices = robotChoice_Data.choice;
participant_ids = robotChoice_Data.id;
stake_types = robotChoice_Data.stakes;
time_spent = robotChoice_Data.timeelapsed;
```

```
User robot choice data imported successfully.
```

Step 2: R Bridge Implementation

```
disp('Initializing R bridge...');

% Configure paths
rscript_path = 'C:\Program Files\R\R-4.4.2\bin\x64\Rscript.exe';
r_script = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\example\DFT_Bounding_Overwatch.R';
csvFile = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\data\Bounding_Overwatch_Data\HumanData_Bounding_Overwatch - 80Split.csv';
outputDir = 'G:\My Drive\myResearch\Research Experimentation\Apollo\apollo\Output_BoundingOverwatch';

% Verify installations
if ~isfile(rscript_path)
    error('Rscript.exe not found at: %s', rscript_path);
elseif ~isfile(r_script)
    error('R script not found at: %s', r_script);
elseif ~isfile(csvFile)
    error('Input CSV not found at: %s', csvFile);
elseif ~isfolder(outputDir)
    warning('Output folder does not exist, creating: %s', outputDir);
    mkdir(outputDir);
```

```
end

% Execute R with JSON output
try
    % Use proper argument formatting
    cmd = sprintf(['"%s" "%s" ', ...
                '-i "%s" -o "%s"'], ...
                rscript_path, r_script, csvFile, outputDir);

[status,result] = system(cmd);

    if status == 0
        % Handle output path (whether directory or file)
        if isfolder(outputDir)
            jsonFile = fullfile(outputDir, 'DFT_output.json');
        else
            jsonFile = outputDir;
        end

        % Parse JSON output
        if exist(jsonFile, 'file')
            jsonText = fileread(jsonFile);
            params = jsondecode(jsonText);

            % Extract parameters with validation
            %Boundedphi1, phi2 parameters
            phi1 = min(max(0, validateParam(params, 'phi1', 0.5)),5); % Ensure non-negative
            phi2 = min(max(0, validateParam(params, 'phi2', 0.8)), 0.99); % Constrain 0-1
            %tau = min(1 + exp(validateParam(params, 'timesteps', 0.5)),100); %Constrain to 100

            %Raw phi1, phi2 parameters
            %phi1 = validateParam(params, 'phi1', 0.5);
            %phi2 = validateParam(params, 'phi2', 0.8);
            tau = 1 + exp(validateParam(params, 'timesteps', 0.5));
            error_sd = min(max(0.1, validateParam(params, 'error_sd', 0.1)), 1); % still clip here

            % Extract attribute weights
            beta_weights = [
                params.b_attr1;
                params.b_attr2;
                params.b_attr3;
                params.b_attr4
            ];

            % Get initial preferences from ASCs
            initial_P = [
                validateParam(params, 'asc_1', 0);
                validateParam(params, 'asc_2', 0);
                validateParam(params, 'asc_3', 0);
            ];

            disp('Estimated Parameters:');
            disp(['phi1: ', num2str(phi1)]);
            disp(['phi2: ', num2str(phi2)]);
            disp(['tau: ', num2str(tau)]);
            disp(['error_sd: ', num2str(error_sd)]);
            disp('Initial Preferences (from ASCs):');
            disp(initial_P');
        else
            error('R output file not found');
        end
    else
        error('R execution failed: %s', result);
    end
catch ME
    disp('Error during R execution:');
    disp(getReport(ME, 'extended'));
    [phi1, phi2, tau, error_sd] = getFallbackParams();
    beta_weights = [0.3; 0.2; 0.4; 0.5]; % Default weights
    initial_P = zeros(3,1); % Neutral initial preferences
end
```

```
Initializing R bridge...
```

Step 3: MDFT Formulation to Calculate Preference Dynamics

(MDFT calculations based on estimated parameters) Create M matrix from current trial's attributes C11-C14 are consequence attributes for Robot 1 C21-C24 are consequence attributes for Robot 2 C31-C34 are consequence attributes for Robot 3

```
for current_trial = 1:height(robotChoice_Data)
    num_attributes = 4;

    M = [
        robotChoice_Data.c11(current_trial), robotChoice_Data.c12(current_trial), robotChoice_Data.c13(current_trial), robotChoice_Data.c14(current_trial);
```

```
    robotChoice_Data.c21(current_trial), robotChoice_Data.c22(current_trial), robotChoice_Data.c23(current_trial), robotChoice_Data.c24(current_trial);
    robotChoice_Data.c31(current_trial), robotChoice_Data.c32(current_trial), robotChoice_Data.c33(current_trial), robotChoice_Data.c34(current_trial)
];


% Normalize M values by dividing by 2 and clamping to [0.01, 1]
%{
M = M / 2;
M = max(0.01, min(1, M));
%}

% --- Global Max Normalization ---
%{

global_max = max(robotChoice_Data{:, {'c11','c12','c13','c14','c21','c22','c23','c24','c31','c32','c33','c34'}}, [], 'all', 'omitnan');
if ~isfinite(global_max) || global_max <= 0
    global_max = 1; % fallback in case of zero or NaN
end

M = M / global_max;              % Normalize by global max
M = max(0.01, min(1, M));        % Clamp to [0.01, 1]
%}

% --- Row-wise Min-Max Normalization ---
%{
for i = 1:size(M, 1)
    row = M(i, :);
    min_val = min(row);
    max_val = max(row);

    if max_val == min_val
        M(i, :) = pmax(0.01, pmin(1, row));  % constant row: clamp only
    else
        norm_row = (row - min_val) / (max_val - min_val);
        M(i, :) = max(0.01, min(1, norm_row));  % clamp to [0.01, 1]
    end
end
%}

attributes = {'C1 - Easy Nav, Low Exposure', 'C2 - Hard Nav, Low Exposure', 'C3 - Easy Nav, High Exposure', 'C4 - Hard Nav, High Exposure'};
beta = beta_weights ./ sum(abs(beta_weights));
beta = beta';

[E_P, V_P, choice_probs, P_tau] = calculateDFTdynamics(...
    phi1, phi2, tau, error_sd, beta, M, initial_P);

% Display results for the trial
disp('=== Trial Analysis ===');
disp(['Trial: ', num2str(current_trial)]);
disp(['Participant: ', num2str(participant_ids(current_trial))]);
disp(['Actual Choice: Robot ', num2str(choices(current_trial))]);

disp('M matrix (alternatives × attributes):');
disp(array2table(M, ...
    'RowNames', {'Robot1','Robot2','Robot3'}, ...
    'VariableNames', attributes));

disp('DFT Results:');
disp(['E_P: ', num2str(E_P', '%.2f  ')]);
disp(['Choice probabilities: ', num2str(choice_probs', '%.3f  ')]);
[~, predicted_choice] = max(choice_probs);
disp(['Predicted choice: Robot ', num2str(predicted_choice)]);
disp(['Actual choice: Robot ', num2str(choices(current_trial))]);
disp(' ');

if predicted_choice == choices(current_trial)
    disp('✓ Prediction matches actual choice');
else
    disp('✗ Prediction differs from actual choice');
end

% Plot evolution
figure;
%plot(0:tau, P_tau);
% Replace the plotting section with:
tau_rounded = round(tau);  % Ensure integer steps
if size(P_tau,2) == tau_rounded+1  % Validate dimensions
    plot(0:tau_rounded, P_tau);
else
    warning('Dimension mismatch: P_tau has %d cols, expected %d',...
            size(P_tau,2), tau_rounded+1);
    plot(P_tau');  % Fallback plot
end
xlabel('Preference Step (\tau)');
ylabel('Preference Strength');
legend({'Robot1','Robot2','Robot3'});
title(sprintf('Preference Evolution (Trial %d)', current_trial));
```

```
    grid on;
end
%{
%% Step 4: Output Results
disp('Saving results to CSV...');
output_table = table(E_P, V_P, P_tau(end,:)', ...
                     'VariableNames', {'ExpectedPreference', 'VariancePreference', 'FinalPreferences'});
writetable(output_table, 'results.csv');
disp('Results saved successfully!');
%}
```

```
=== Trial Analysis ===
Trial: 1
Participant: 141831
Actual Choice: Robot 1
M matrix (alternatives × attributes):
              C1 - Easy Nav, Low Exposure    C2 - Hard Nav, Low Exposure    C3 - Easy Nav, High Exposure    C4 - Hard Nav, High Exposure
              ___________________________    ___________________________    ____________________________    ____________________________

    Robot1               1.187                         0.61442                         0.69131                          0.1187
    Robot2              1.1089                         0.52816                         0.69168                         0.11089
    Robot3              1.1885                          0.6077                         0.69963                         0.11885

DFT Results:
E_P: -0.00   0.04  -0.03
Choice probabilities: 0.300  0.471  0.229
Predicted choice: Robot 2
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 2
Participant: 141831
Actual Choice: Robot 1
M matrix (alternatives × attributes):
              C1 - Easy Nav, Low Exposure    C2 - Hard Nav, Low Exposure    C3 - Easy Nav, High Exposure    C4 - Hard Nav, High Exposure
              ___________________________    ___________________________    ____________________________    ____________________________

    Robot1              1.5545                         0.85641                         0.85351                         0.15545
    Robot2              1.4467                          0.7275                         0.86391                         0.14467
    Robot3              1.3317                         0.71925                         0.74565                         0.13317

DFT Results:
E_P: -0.06  -0.00   0.07
Choice probabilities: 0.158  0.278  0.565
Predicted choice: Robot 3
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 3
Participant: 125802
Actual Choice: Robot 3
M matrix (alternatives × attributes):
              C1 - Easy Nav, Low Exposure    C2 - Hard Nav, Low Exposure    C3 - Easy Nav, High Exposure    C4 - Hard Nav, High Exposure
              ___________________________    ___________________________    ____________________________    ____________________________

    Robot1              1.8598                          1.0972                         0.94855                         0.18598
    Robot2              1.8077                          1.0814                         0.90712                         0.18077
    Robot3              1.7338                          1.0234                         0.88385                         0.17338

DFT Results:
E_P: -0.03   0.01   0.03
Choice probabilities: 0.223  0.355  0.421
Predicted choice: Robot 3
Actual choice: Robot 3

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 4
Participant: 125802
Actual Choice: Robot 1
M matrix (alternatives × attributes):
              C1 - Easy Nav, Low Exposure    C2 - Hard Nav, Low Exposure    C3 - Easy Nav, High Exposure    C4 - Hard Nav, High Exposure
              ___________________________    ___________________________    ____________________________    ____________________________

    Robot1              1.2533                         0.73546                         0.64312                         0.12533
    Robot2               1.472                         0.87423                           0.745                          0.1472
    Robot3              1.3803                           0.834                         0.68433                         0.13803

DFT Results:
E_P: 0.08  -0.06  -0.02
Choice probabilities: 0.625  0.152  0.224
Predicted choice: Robot 1
Actual choice: Robot 1
```

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 5
Participant: 125802
Actual Choice: Robot 2
M matrix (alternatives × attributes):

	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.6563	0.96666	0.85526	0.16563
Robot2	1.753	0.98833	0.93993	0.1753
Robot3	1.8425	1.1629	0.86388	0.18425

DFT Results:
E_P: 0.07 -0.01 -0.05
Choice probabilities: 0.563 0.269 0.168
Predicted choice: Robot 1
Actual choice: Robot 2

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 6
Participant: 125802
Actual Choice: Robot 1
M matrix (alternatives × attributes):

	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.3338	0.6213	0.84591	0.13338
Robot2	1.5924	0.85906	0.89253	0.15924
Robot3	1.5687	0.82302	0.90256	0.15687

DFT Results:
E_P: 0.10 -0.04 -0.06
Choice probabilities: 0.695 0.168 0.137
Predicted choice: Robot 1
Actual choice: Robot 1

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 7
Participant: 125802
Actual Choice: Robot 3
M matrix (alternatives × attributes):

	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.1753	0.64077	0.65203	0.11753
Robot2	1.1703	0.6031	0.68426	0.11703
Robot3	1.2412	0.71424	0.65113	0.12412

DFT Results:
E_P: 0.02   0.02 -0.03
Choice probabilities: 0.395 0.381 0.224
Predicted choice: Robot 1
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 8
Participant: 125802
Actual Choice: Robot 1
M matrix (alternatives × attributes):

	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.3997	0.84229	0.69735	0.13997
Robot2	1.471	0.89837	0.71978	0.1471
Robot3	1.4976	0.92025	0.72715	0.14976

DFT Results:
E_P: 0.04   0.00 -0.04
Choice probabilities: 0.474 0.321 0.205
Predicted choice: Robot 1
Actual choice: Robot 1

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 9
Participant: 125802
Actual Choice: Robot 2
M matrix (alternatives × attributes):

	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.4508	0.94819	0.64768	0.14508
Robot2	1.4465	0.90478	0.68638	0.14465

Robot3	1.5693	0.96403	0.76219	0.15693

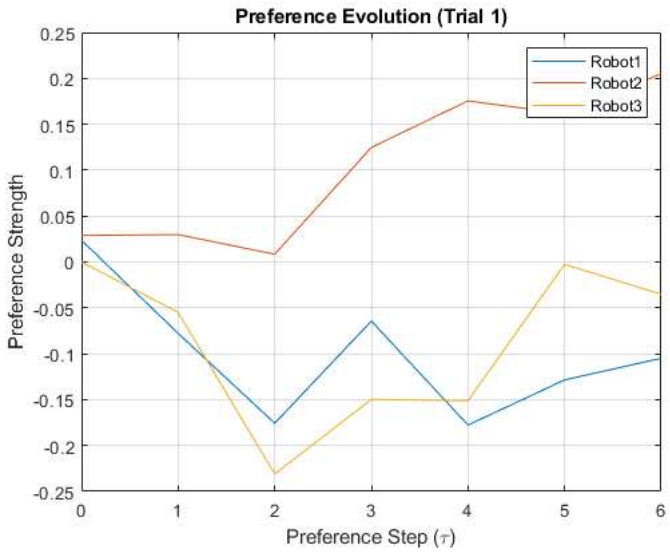
DFT Results:
E_P: 0.05 0.04 -0.08
Choice probabilities: 0.448 0.422 0.130
Predicted choice: Robot 1
Actual choice: Robot 2

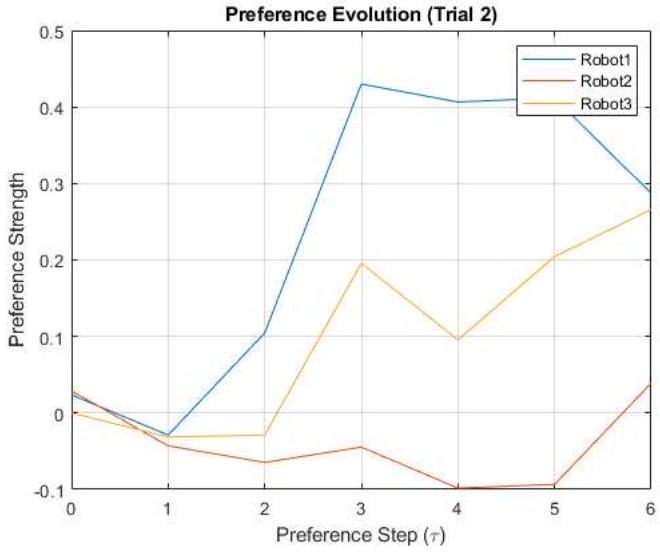
✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 10
Participant: 141831
Actual Choice: Robot 2
M matrix (alternatives × attributes):

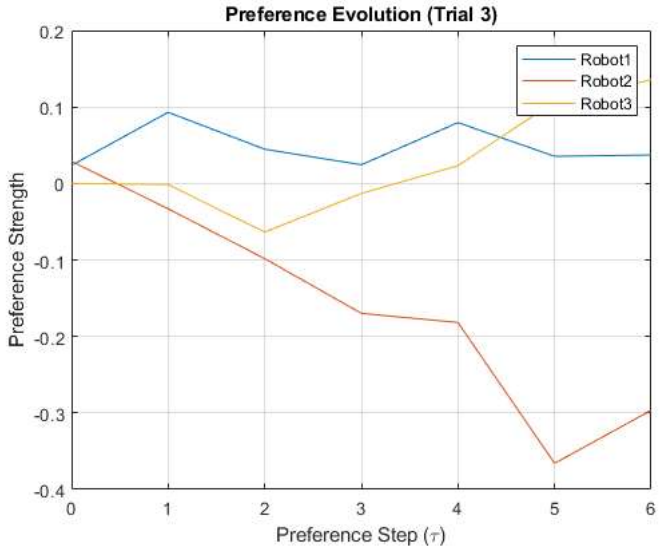
	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	1.292	0.74171	0.67946	0.1292
Robot2	1.3577	0.7572	0.73625	0.13577
Robot3	1.2916	0.76907	0.65163	0.12916

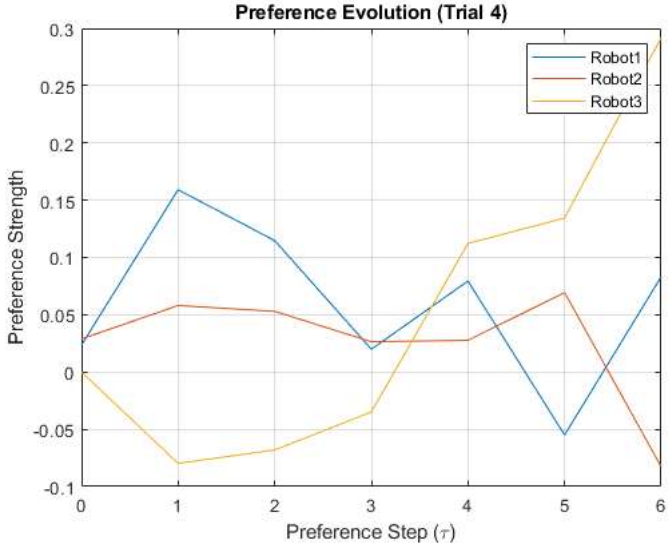
DFT Results:
E_P: 0.02 -0.03 0.01
Choice probabilities: 0.401 0.248 0.350
Predicted choice: Robot 1
Actual choice: Robot 2

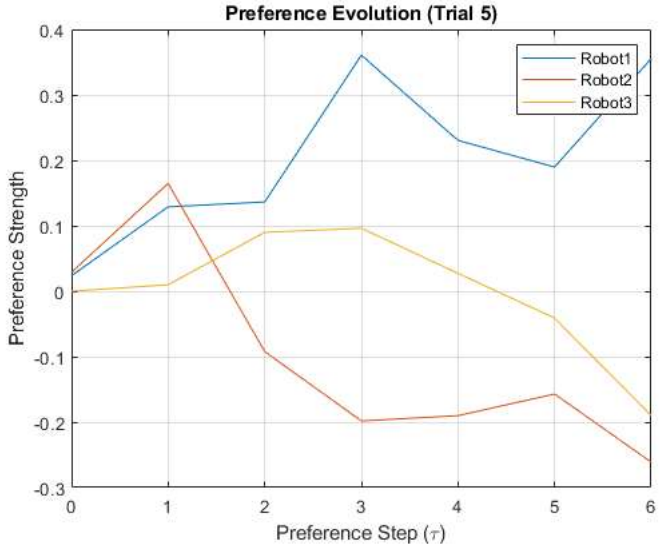
✗ Prediction differs from actual choice

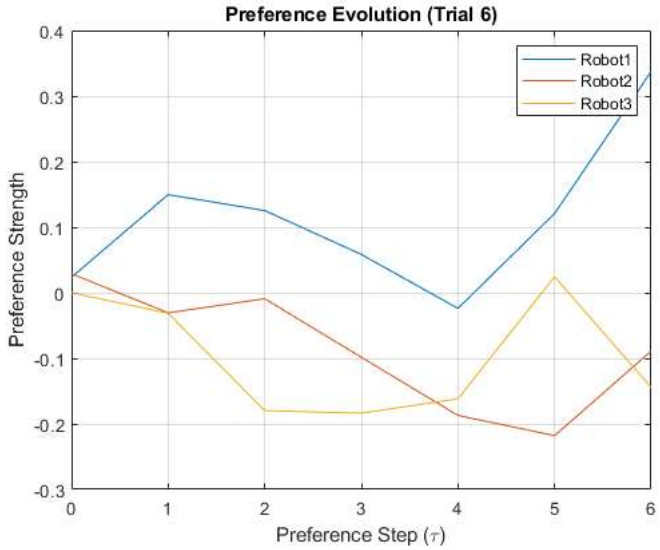


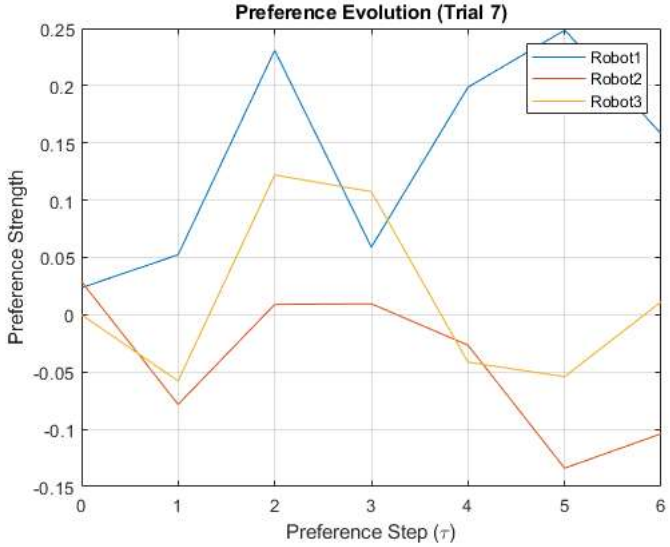


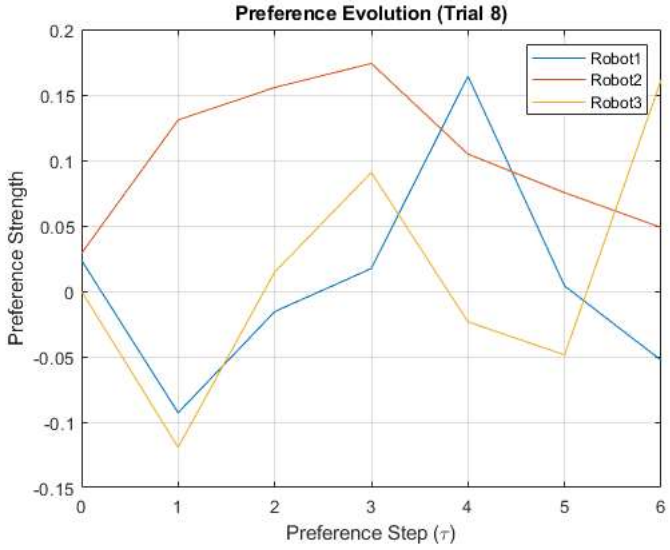

Preference Evolution (Trial 3)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)

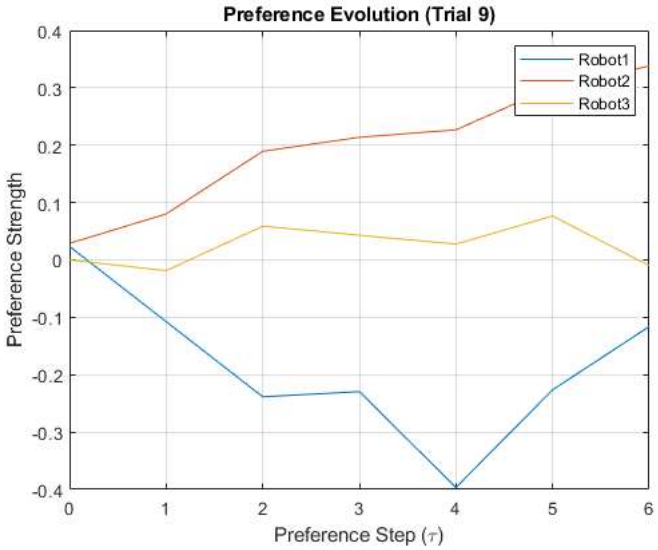

Preference Evolution (Trial 4)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)

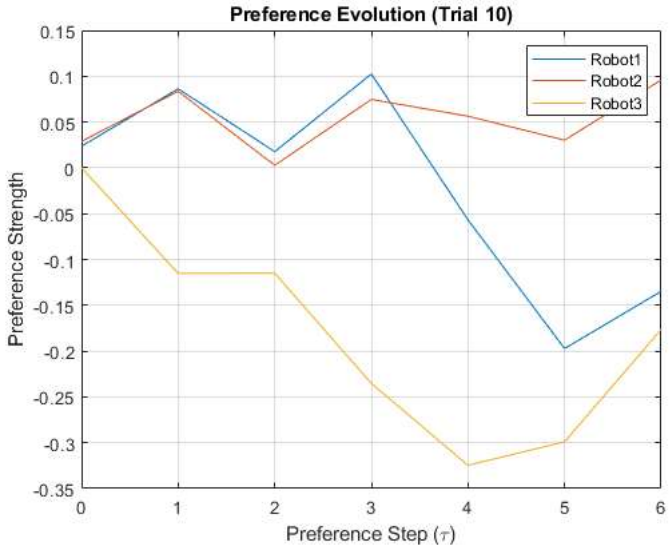

Preference Evolution (Trial 5)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)


Preference Evolution (Trial 6)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)


Preference Evolution (Trial 7)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)


Preference Evolution (Trial 8)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)





Helper Functions

```
function param = validateParam(params, name, default)
    if isfield(params, name) && isnumeric(params.(name))
        param = params.(name);
    else
        warning('Using default for %s', name);
        param = default;
    end
end

function [phi1, phi2, tau, error_sd] = getFallbackParams()
    phi1 = 0.5 + 0.1*randn();
    phi2 = 0.8 + 0.1*randn();
    tau = 10 + randi(5);
    error_sd = 0.1 + 0.05*rand();
    warning('Using randomized default parameters');
end
```

```
Estimated Parameters:
phi1: 5
phi2: 0.1
tau: 5.9998
error_sd: 0.1
Initial Preferences (from ASCs):
    0.0236    0.0289         0
```

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