## 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 3a: MDFT Formulation to Calculate Preference Dynamics in Parallel

```
%%{
% (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 frame
    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
%%}
```

```
=== Trial Analysis ===
Trial: 1
Participant: 141831
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                           0.51269                        0.48731                           0.01
    Robot2                 1                           0.52794                        0.47206                           0.01
    Robot3                 1                           0.52695                        0.47305                           0.01

DFT Results:
E_P: -6.95   3.83   3.11
Choice probabilities: 0.000  0.999  0.001
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 2
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                           0.54352                        0.45648                           0.01
    Robot2                 1                            0.5377                         0.4623                           0.01
    Robot3                 1                           0.54546                        0.45454                           0.01

DFT Results:
E_P: 1.19  -4.12   2.94
Choice probabilities: 0.000  0.000  1.000
Predicted choice: Robot 3
Actual choice: Robot 2

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 3
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                           0.55753                        0.44247                           0.01
    Robot2                 1                           0.56745                        0.43255                           0.01
    Robot3                 1                           0.57163                        0.42837                           0.01

DFT Results:
E_P: -6.18   1.48   4.70
Choice probabilities: 0.000  0.000  1.000
Predicted choice: Robot 3
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 4
Participant: 141831
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                           0.57827                        0.42173                           0.01
    Robot2                 1                            0.6312                         0.3688                           0.01
    Robot3                 1                           0.54961                        0.45039                           0.01

DFT Results:
E_P: -0.46   2.65  -2.19
Choice probabilities: 0.000  1.000  0.000
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
```

=== Trial Analysis ===
Trial: 5
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 | 0.53492 | 0.46508 | 0.01 |
| Robot2 | 1 | 0.40855 | 0.59145 | 0.01 |
| Robot3 | 1 | 0.4405 | 0.5595 | 0.01 |

DFT Results:
E_P: 1.73  -1.28  -0.44
Choice probabilities: 1.000  0.000  0.000
Predicted choice: Robot 1
Actual choice: Robot 1

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 6
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 | 0.61508 | 0.38492 | 0.01 |
| Robot2 | 1 | 0.58388 | 0.41612 | 0.01 |
| Robot3 | 1 | 0.57145 | 0.42855 | 0.01 |

DFT Results:
E_P: 4.96  -1.24  -3.72
Choice probabilities: 1.000  0.000  0.000
Predicted choice: Robot 1
Actual choice: Robot 2

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 7
Participant: 141831
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 | 0.50762 | 0.49238 | 0.01 |
| Robot2 | 1 | 0.54112 | 0.45888 | 0.01 |
| Robot3 | 1 | 0.52591 | 0.47409 | 0.01 |

DFT Results:
E_P: -5.81   5.47   0.33
Choice probabilities: 0.000  1.000  0.000
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 8
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 | 0.54115 | 0.45885 | 0.01 |
| Robot2 | 1 | 0.57935 | 0.42065 | 0.01 |
| Robot3 | 1 | 0.54946 | 0.45054 | 0.01 |

DFT Results:
E_P: -3.81   5.58  -1.78
Choice probabilities: 0.000  1.000  0.000
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 9
Participant: 141831
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 | 0.52853 | 0.47147 | 0.01 |
| Robot2 | 1 | 0.509 | 0.491 | 0.01 |
| Robot3 | 1 | 0.578 | 0.422 | 0.01 |

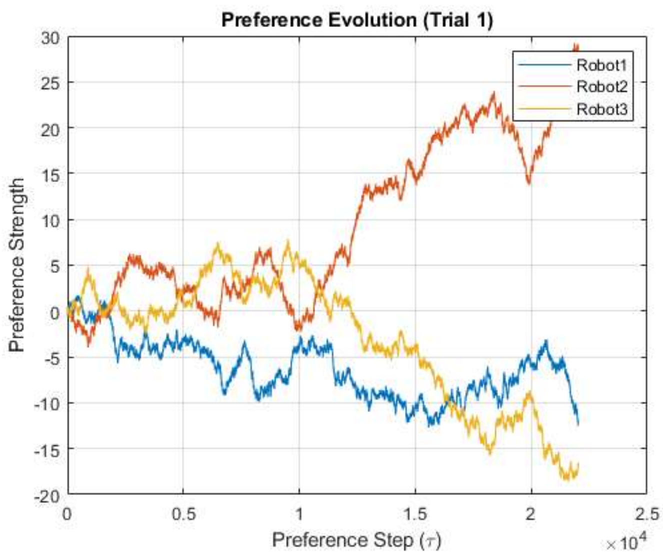
DFT Results:
E_P: -0.79  -2.37   3.16
Choice probabilities: 0.000  0.000  1.000
Predicted choice: Robot 3
Actual choice: Robot 3

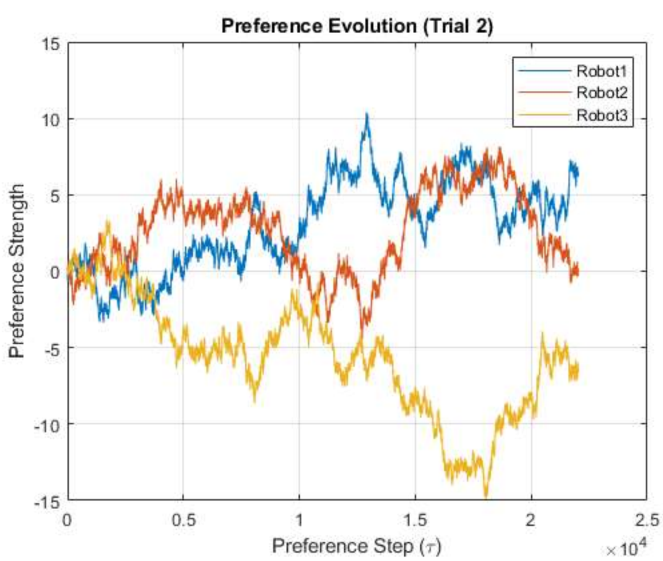
✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 10
Participant: 125802
Actual Choice: Robot 3
M matrix (alternatives × attributes):

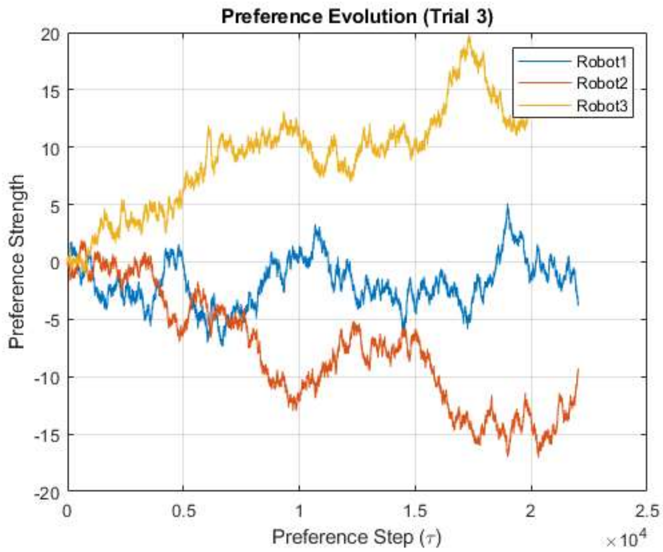
| | C1 - Easy Nav, Low Exposure | C2 - Hard Nav, Low Exposure | C3 - Easy Nav, High Exposure | C4 - Hard Nav, High Exposure |
|---|---|---|---|---|
| Robot1 | 1 | 0.51605 | 0.48395 | 0.01 |
| Robot2 | 1 | 0.52401 | 0.47599 | 0.01 |
| Robot3 | 1 | 0.54193 | 0.45807 | 0.01 |

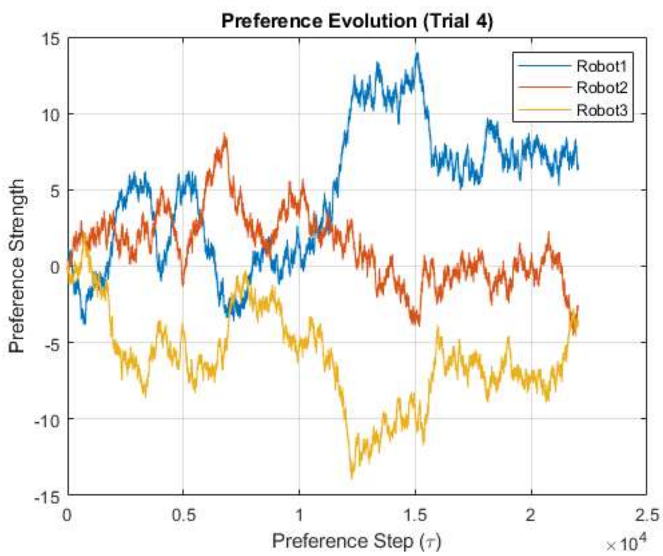
DFT Results:
E_P: -5.33  -1.56   6.89
Choice probabilities: 0.000  0.000  1.000
Predicted choice: Robot 3
Actual choice: Robot 3

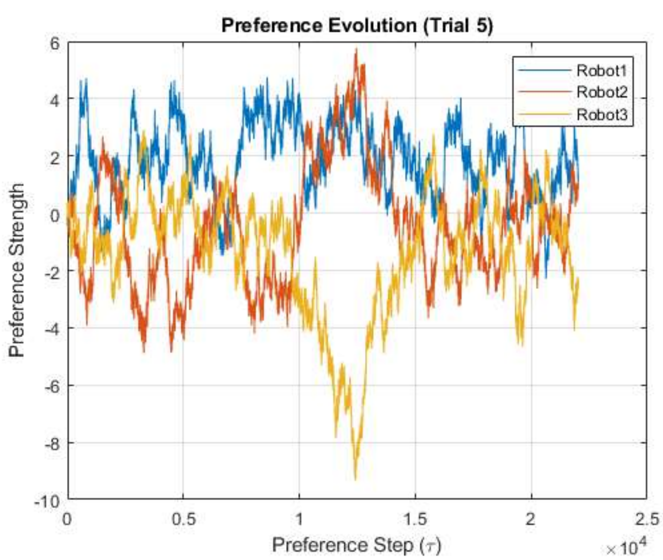
✓ Prediction matches actual choice

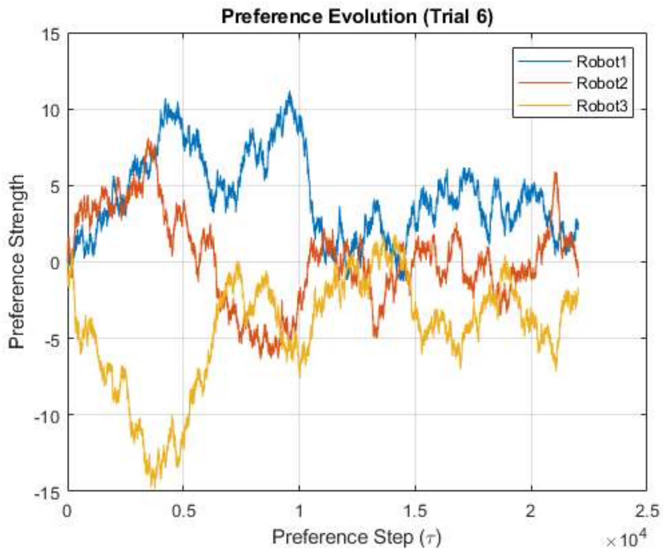


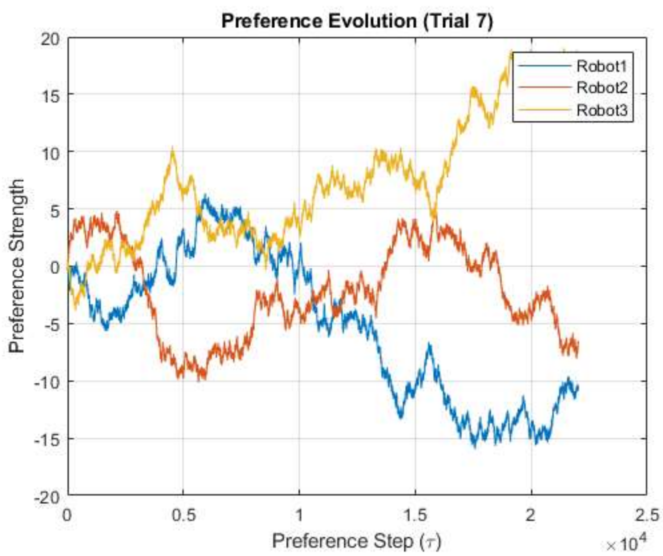



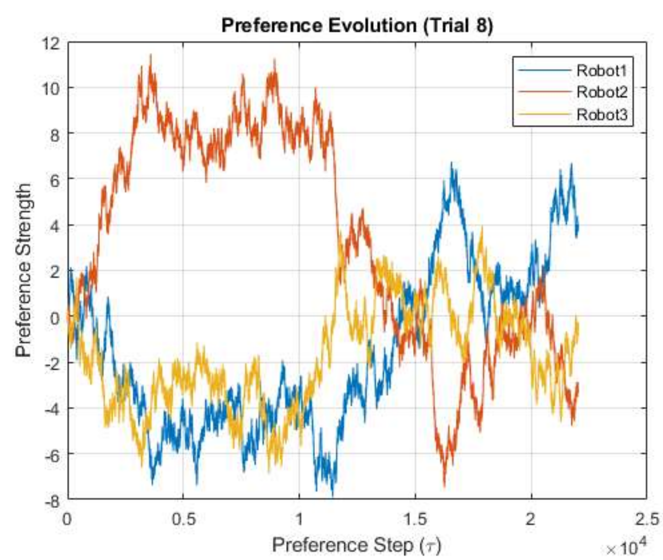

Preference Evolution (Trial 3)
Robot1
Robot2
Robot3
Preference Strength
Preference Step ($\tau$)
$\times 10^4$

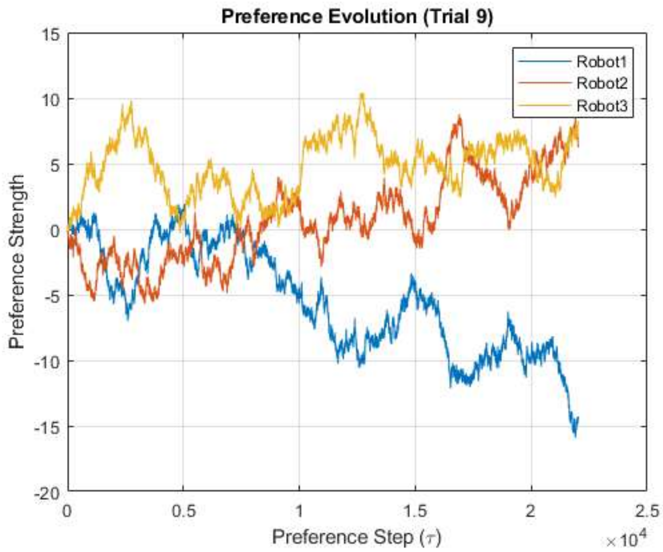

Preference Evolution (Trial 4)
Robot1
Robot2
Robot3
Preference Strength
Preference Step ($\tau$)
$\times 10^4$

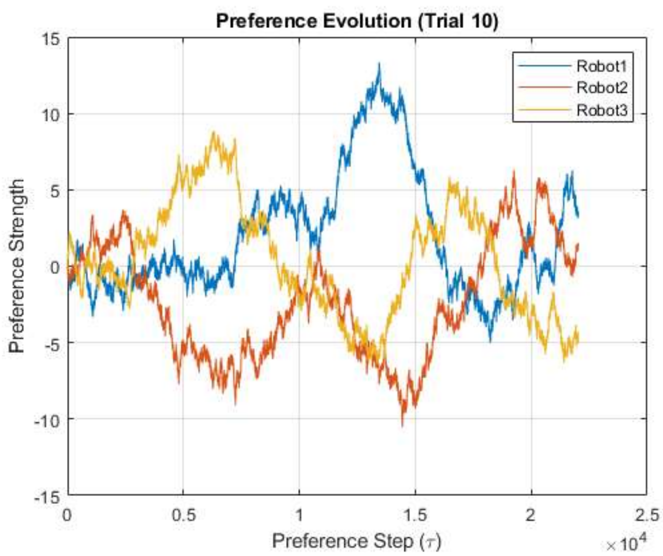

Preference Evolution (Trial 5)
Robot1
Robot2
Robot3
Preference Strength
Preference Step ($\tau$)
$\times 10^4$


Preference Evolution (Trial 6)
15
10
5
0
-5
-10
-15
Preference Strength
0
0.5
1
1.5
2
2.5
Preference Step ($\tau$)
$\times 10^4$
Robot1
Robot2
Robot3


Preference Evolution (Trial 7)
20
15
10
5
0
-5
-10
-15
-20
Preference Strength
0
0.5
1
1.5
2
2.5
Preference Step ($\tau$)
$\times 10^4$
Robot1
Robot2
Robot3


Preference Evolution (Trial 8)
12
10
8
6
4
2
0
-2
-4
-6
-8
Preference Strength
0
0.5
1
1.5
2
2.5
Preference Step ($\tau$)
$\times 10^4$
Robot1
Robot2
Robot3




**Step 3b: MDFT Formulation with State Continuity**

```
%{
% Initialize preference state tracking
if ~exist('P_final_prev', 'var')
    P_final_prev = initial_P; % Use estimated initial preferences for first trial
end

for current_trial = 1:height(robotChoice_Data)
    % Create M matrix for current trial
    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 beta weights
    beta = beta_weights ./ sum(abs(beta_weights));

    % Calculate DFT dynamics using previous trial's final state
    [E_P, V_P, choice_probs, P_tau] = calculateDFTdynamics(...
        phi1, phi2, tau, error_sd, beta, M, P_final_prev);

    % Store final preference state for next trial
    P_final_prev = P_tau(:, end);

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

    disp('Initial Preferences (from previous trial):');
    disp(array2table(P_tau(:,1)', 'VariableNames', {'Robot1','Robot2','Robot3'})); % Fixed this line
```

```
    disp('Final Preferences:');
    disp(array2table(P_tau(:,end)', 'VariableNames', {'Robot1','Robot2','Robot3'})); % Fixed this line

    % Enhanced plotting with initial/final state markers
    figure;
    plot(0:tau, P_tau, 'LineWidth', 2);
    hold on;
    % Mark initial state
    scatter(zeros(3,1), P_tau(:,1), 100, 'filled');
    % Mark final state
    scatter(tau*ones(3,1), P_tau(:,end), 100, 'x', 'LineWidth', 2);
    hold off;

    xlabel('Preference Step (\tau)');
    ylabel('Preference Strength');
    legend({'Robot1','Robot2','Robot3','Initial State','Final State'});
    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!');
%}
```

```
Saving results to CSV...
```

```
Error using table
All table variables must have the same number of rows.

Error in main_BoundingOverwatch (line 302)
output_table = table(E_P, V_P, P_tau(end,:)', ...
```

### 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: 3.499
phi2: 0.1
tau: 22027.4658
error_sd: 0.1
Initial Preferences (from ASCs):
    0.0152    0.0157         0
```