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)
```

```matlab
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)
];

% --- Global Min-Max Normalization ---
% Extract all attribute columns from the dataset
all_attributes = robotChoice_Data{:, {'c11','c12','c13','c14','c21','c22','c23','c24','c31','c32','c33','c34'}};

% Calculate global min and max (ignore NaN/Inf)
global_min = double(min(all_attributes(:), [], 'omitnan'));
global_max = double(max(all_attributes(:), [], 'omitnan'));

% Normalize M to [0, 1] range
if global_max ~= global_min  % Avoid division by zero
    M = (M - global_min) / (global_max - global_min);
else
    M = zeros(size(M));  % Fallback if all values are identical
end

% Optional: Clamp to [0.01, 1] to avoid extreme values
M = max(0.01, min(1, M));

% 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: 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              0.58363                        0.32514                        0.27354                          0.01505
    Robot2               0.6557                        0.38708                        0.29088                         0.022257
    Robot3              0.43313                        0.13411                        0.29902                             0.01

DFT Results:
E_P: 0.02   0.03  -0.04
Choice probabilities: 0.387  0.411  0.202
Predicted choice: Robot 2
Actual choice: Robot 2

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 2
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              0.74114                        0.44156                        0.33037                         0.030801
    Robot2              0.65408                        0.42101                        0.25517                         0.022095
    Robot3              0.72217                        0.40993                        0.34114                         0.028904

DFT Results:
E_P: -0.00   0.03  -0.03
Choice probabilities: 0.320  0.438  0.242
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 3
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              0.89267                        0.50616                        0.43246                         0.045954
    Robot2               0.8267                        0.46271                        0.40334                         0.039357
    Robot3              0.85081                        0.48306                        0.40951                         0.041768

DFT Results:
E_P: 0.00   0.01  -0.01
Choice probabilities: 0.339  0.352  0.309
Predicted choice: Robot 2
Actual choice: Robot 2

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 4
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              0.89597                        0.48477                        0.45749                         0.046284
    Robot2              0.84016                        0.45963                        0.42124                         0.040704
    Robot3              0.93702                        0.53089                        0.45652                         0.050389

DFT Results:
E_P: -0.00   0.01  -0.01
Choice probabilities: 0.324  0.363  0.313
Predicted choice: Robot 2
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 5
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              0.93743                        0.54013                        0.44773                          0.05043
    Robot2              0.89425                        0.49485                        0.44552                         0.046112
    Robot3              0.95204                        0.55263                         0.4513                         0.051891

DFT Results:
E_P: 0.01  -0.00  -0.00
Choice probabilities: 0.360  0.326  0.314
Predicted choice: Robot 1
Actual choice: Robot 3

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 6
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                        0.57297                        0.48371                         0.056687
    Robot2              0.97741                        0.56671                        0.46513                         0.054428
    Robot3              0.96161                        0.52266                         0.4918                         0.052848

DFT Results:
E_P: 0.01   0.02  -0.02
Choice probabilities: 0.356  0.383  0.261
Predicted choice: Robot 2
Actual choice: Robot 2

✓ Prediction matches actual choice
=== Trial Analysis ===
Trial: 7
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              0.73561                        0.44317                        0.32268                         0.030248
    Robot2              0.76977                        0.48297                        0.32047                         0.033664
    Robot3              0.70348                        0.40414                        0.32638                         0.027035

DFT Results:
E_P: 0.01   0.02  -0.02
Choice probabilities: 0.347  0.385  0.268
Predicted choice: Robot 2
Actual choice: Robot 2

✓ Prediction matches 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              0.68675                        0.33356                        0.37855                         0.025362
    Robot2              0.62902                        0.34378                        0.30482                         0.019589
    Robot3              0.57617                        0.30658                        0.28389                         0.014304

DFT Results:
E_P: -0.02   0.02   0.00
Choice probabilities: 0.267  0.391  0.342
```

Predicted choice: Robot 2
Actual choice: Robot 1

✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 9
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	0.61349	0.31259	0.31893	0.018036
Robot2	0.61071	0.29139	0.33708	0.017758
Robot3	0.65063	0.35396	0.31843	0.02175

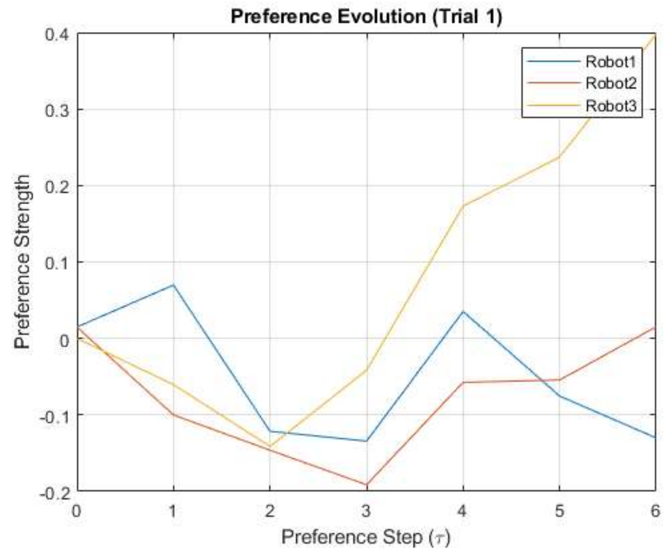
DFT Results:
E_P: 0.01 -0.01   0.00
Choice probabilities: 0.354 0.308 0.337
Predicted choice: Robot 1
Actual choice: Robot 3

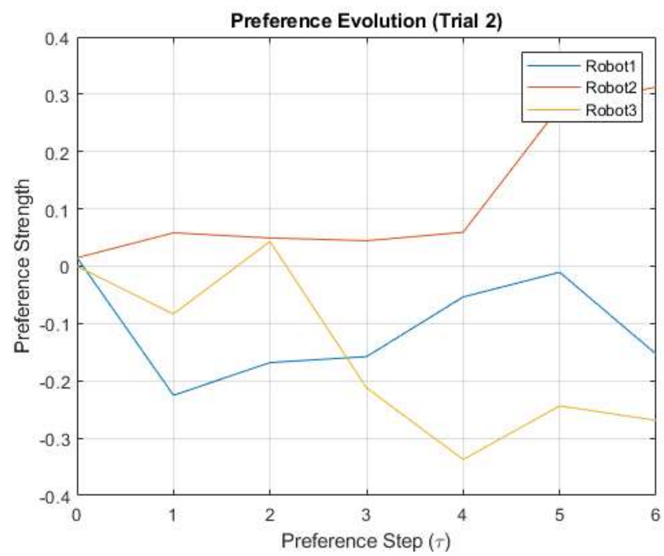
✗ Prediction differs from actual choice
=== Trial Analysis ===
Trial: 10
Participant: 125802
Actual Choice: Robot 1
M matrix (alternatives × attributes):

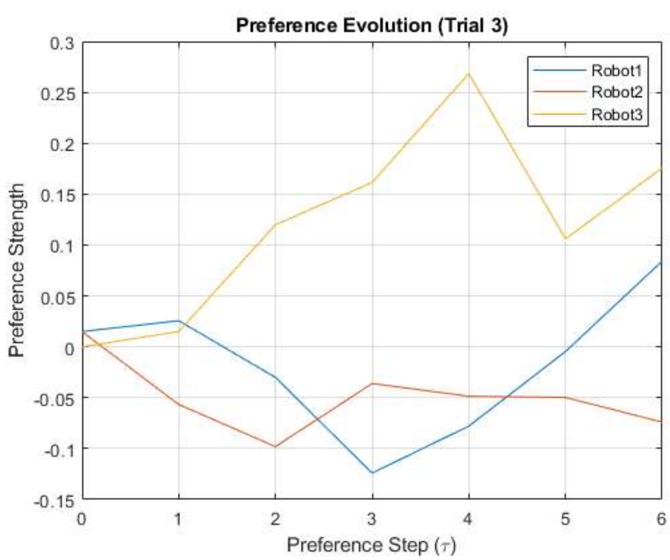
	C1 - Easy Nav, Low Exposure	C2 - Hard Nav, Low Exposure	C3 - Easy Nav, High Exposure	C4 - Hard Nav, High Exposure
Robot1	0.6574	0.3659	0.31392	0.022427
Robot2	0.78055	0.44402	0.37127	0.034742
Robot3	0.72891	0.42138	0.33712	0.029578

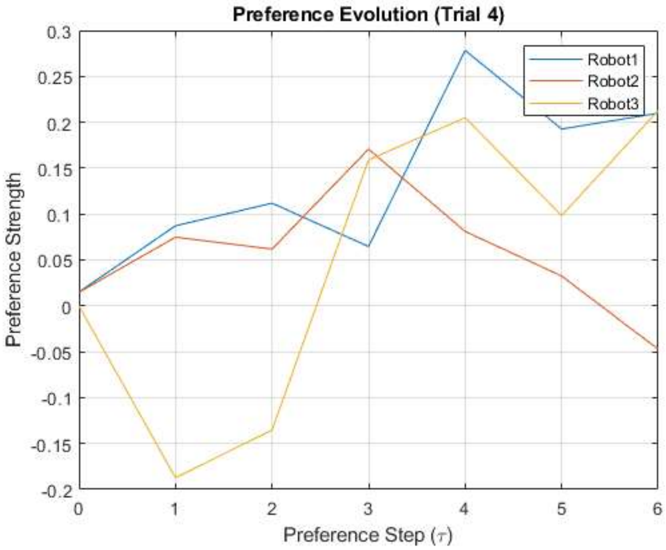
DFT Results:
E_P: 0.01 -0.00 -0.00
Choice probabilities: 0.359 0.326 0.315
Predicted choice: Robot 1
Actual choice: Robot 1

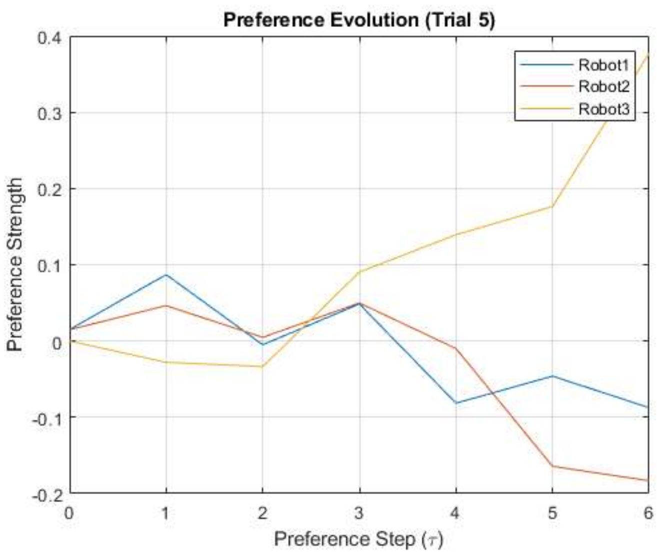
✓ Prediction matches actual choice

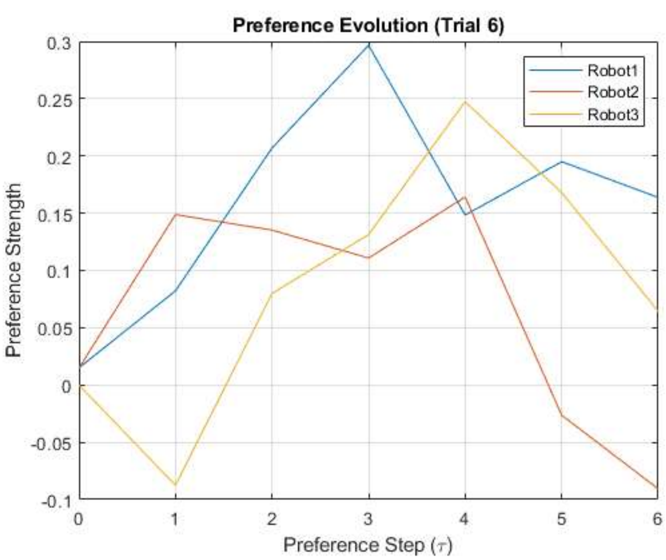

Preference Evolution (Trial 1)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0
1
2
3
4
5
6

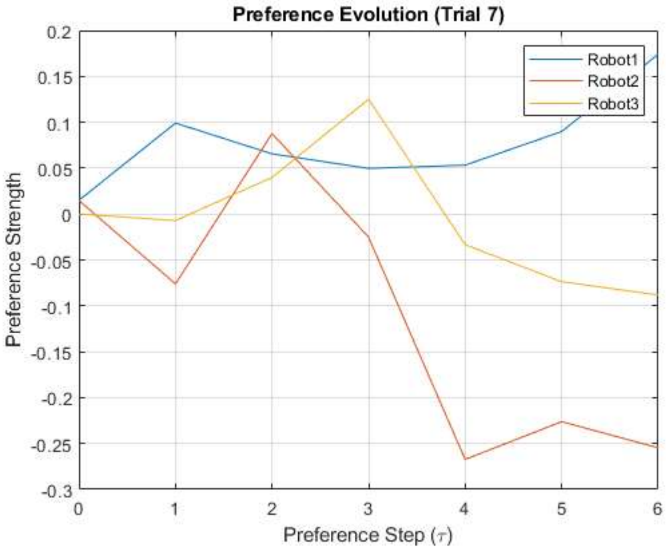

Preference Evolution (Trial 2)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1
2
3
4
5
6

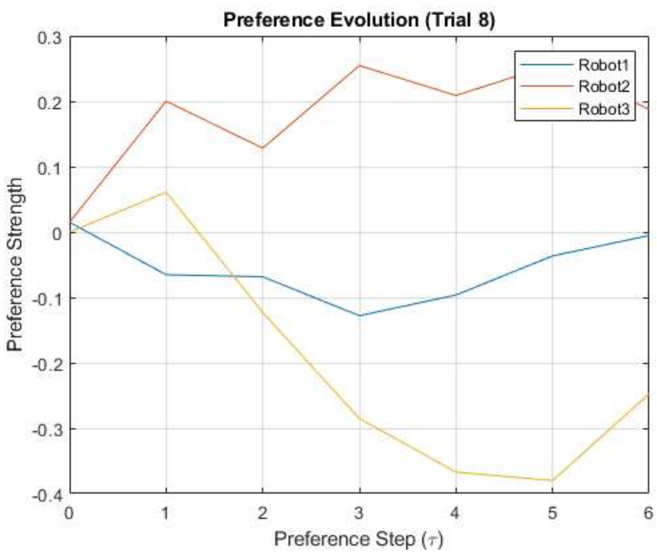

Preference Evolution (Trial 3)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
1
2
3
4
5
6

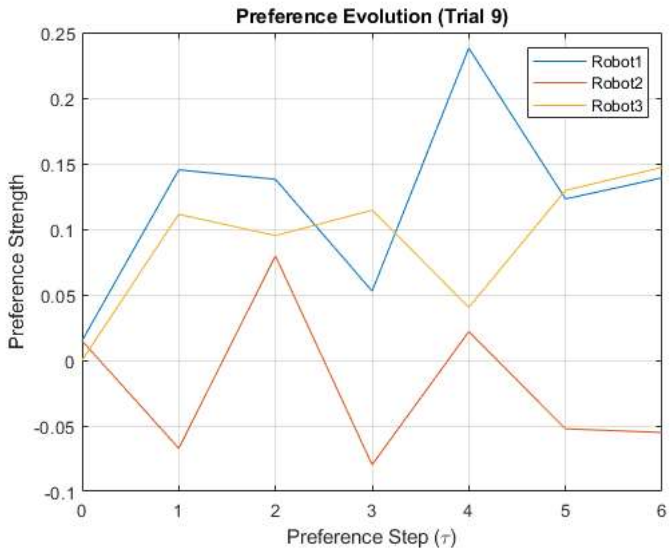

Preference Evolution (Trial 4)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)

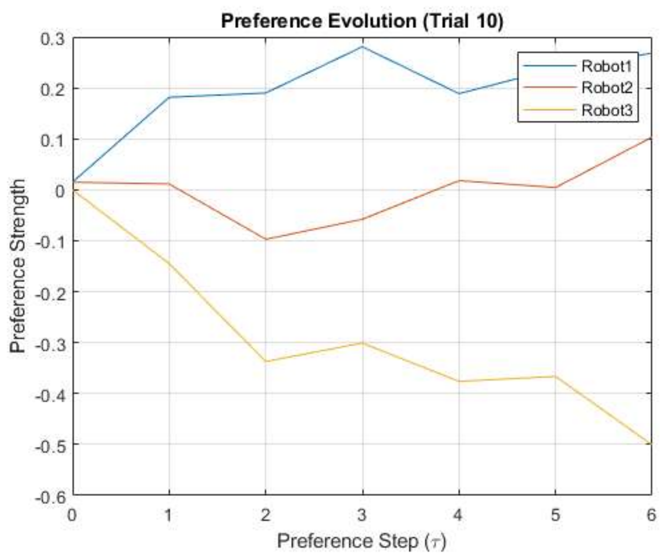

Preference Evolution (Trial 5)
Robot1
Robot2
Robot3
Preference Strength
Preference Step (τ)


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


Preference Evolution (Trial 7)
Robot1
Robot2
Robot3
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0
1
2
3
4
5
6
Preference Strength
Preference Step (τ)


Preference Evolution (Trial 8)
Robot1
Robot2
Robot3
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1
2
3
4
5
6
Preference Strength
Preference Step (τ)





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!');
%}
```

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: 2.1035
phi2: 0.1
tau: 5.9998
error_sd: 0.1
Initial Preferences (from ASCs):
    0.0150    0.0148         0
```

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