Experiment Procedure

The following provides the step-by-step procedure for the human study carried out as part of the dissertation of Finlo Heath, MSc Robotics.
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I. INTRODUCTION

When you first meet the participant, you must carry out the following steps:

1. Greet participants with a consistent positive mood. Your sentiment can affect their perception of the study trials.
2. Give the participant the information sheet and have them read it carefully.
3. check that they understand all the information there.
4. hand them the privacy statement to read through.
5. Finally, provide them with the informed consent form to sign if they are happy.

II. EXPLAIN AND DEMONSTRATE

Once the participant has signed the consent form:

1. Explain the underlying task: Whenever the participant notices a vibration on the arm, press the foot pedal as swiftly as possible. After this, they will verbally provide the researcher with a value for the intensity of the vibration signal ranging from 1 LOWEST to 6 HIGHEST. They are trying to estimate the intensity level of the five correctly. We will see if their perception of intensity is affected by load.
2. Provide verbal confirmation that there will be three conditions. Explain the following cognitive load tasks:
    - Counting backwards in multiples of 7.
    - Building task with Duplo.
3. Show participants a demonstration video of each condition. Video suitable as don't need to set up arm twice.
4. Check again with participants whether they are happy they understand the task. Do not proceed until they do.

III. HARDWARE SET UP

1. Ensure the hand resting station is in place for the user.
2. Strap the vibrotactile sleeve to the participant and ensure no pinching. Align as specified on the band.
3. Strap the EMG band on the participant, best guess on placement.
4. Strap hand to the participant, wrist just beyond contact, tight.

5. Turn the hand on. Launch Covvi Go, check config set to *participant*. Check the signals.
6. Adjust electrode band until clear signals for both. Then calibrate for the user.
7. Check hand responsive and the user happy. If not, repeat steps 5 and 6 until working.
8. Ensure vibrotactile feedback and foot-pedal working, use test script for this.
9. Duplo pieces should be disassembled but not shuffled.

IV. TRAINING & CALIBRATION

1. Run *VibrationCalibration* script.
2. Perform FSR band tightness check.
3. ASK USER **"which intensity they prefer out of the five"** - deliver the five intensities three times over with one-second intervals. Record the answer.
4. give the user some time to practice with the pedal.
5. give the user some time to practice controlling the hand (NOT BUILDING).

V. SELECT CONDITION ORDER

Choose the condition order: abc, acb, bac, bca, cab, cba.

1. Record the condition order.
2. Inform the participant.
3. Move to the appropriate section below.

VI. CONDITION A: NO COGNITIVE LOAD

For this condition, we apply the following steps:

1. At set intervals of different lengths, apply vibrotactile feedback to the user.
2. Feedback will be of different intensity levels, say 1-6.
3. When they notice the feedback, the user must press the foot pedal as quickly as possible.
4. Researcher records:
   - time stamp of each signal.
   - intensity value of the signal from 1-6.
   - user time to respond. Specific recording value for missed signal.
   - user rating of intensity from 1 (Lowest) to 6 (Highest). Specific recording value for missed signal.
5. Researcher gives user questionnaire.

VII. CONDITION B: VERBAL TASK

For this condition, we apply the following steps:

1. Participant counts backwards in increments of seven from four hundred.
2. After each vibration, they are given a new number to avoid them having to remember where they were.
3. Steps 1-4 of section VI repeated while they perform this task.
4. Researcher gives user questionnaire.

VIII. CONDITION C: PHYSICAL TASK TASK

For this condition, we apply the following steps:

1. Participant uses their left natural hand and right prosthetic hand to follow the instructions and build a Duplo set. Rules are: **covvi hand must pick up the blocks but can pass to left natural hand. Building must occur in the air - no bracing against the table. You are not allowed to use your right natural hand at any point.**
2. Steps 1-4 of section VI repeated while they perform this task. In addition, the researcher records build task performance. Specifically, the number of bricks assembled out of the total provided. This aims to encourage participants not to ignore progress in the task, and to give it their full attention.
3. Researcher gives user questionnaire.

IX. USER DE-BRIEF

Once the user has completed both conditions:

1. Unstrap the user from all hardware and place the hand back in the resting station.
2. Provide the user with a reminder of the privacy policy and their right to withdraw their data within seven days.
3. Answer any further questions they have and reward them with a sweet if they would like one.

X. ANALYSIS OPTIONS

We are looking to discern

1. How does cognitive load, and physical load affect reaction time? Is the difference statistically significant?
2. Is there a statistically significant difference in performance in each condition at different intensities?
3. What is the ideal intensity for when the hand is passive (no cognitive or physical load)? Ideal intensity will be the fastest possible reaction time with the intensity being at the preferred intensity and as perceivable as possible.
4. What is the ideal intensity when the hand is in use (under a cognitive/physical load)?
5. How much variance is there between participants in ideal intensities for these conditions?

XI. ANALYSIS MOTIVATION

By doing these analyses, we aim to find out

1. The ideal intensity levels to switch between when the hand is passive vs. in use. Optimise this to avoid missed signals, while being as low intensity as possible to minimise prosthetic battery use and user maintain a level perceived intensity of vibration across load.
2. Whether you should switch between the two intensity levels or phase from low to high based on electrode intensity readings.

   If this vibrotactile feedback is implemented, it will enable pleasant yet consistently perceivable, efficient emergency alerts for the prosthetic device. This would encourage users to trust the safety of operating the device without visual confirmation, enabling them to train to use it more like the natural hand. Advances in soft tactile feedback such as squeezing and skin shear would work well in conjunction with this end, providing the user with moment-to-moment haptic feedback.