User Intent Communication in Robot-Assisted Shopping for the Blind

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Introduction

- We have been working on independent shopping solutions for the visually impaired.
- We have built RoboCart, a robot shopping assistant for the blind.
- RoboCart has been field-tested in a series of longitudinal shopping experiments with visually impaired participants at Lee's MarketPlace, a supermarket in Logan, UT.
- This presentation will focus on how visually impaired shoppers can communicate their intent to RoboCart through product selection.

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- Background on RobotCart.
- Shopping task analysis.
- Blind communication modalities in assisted shopping.
- Research hypotheses.
- Experiments with 5 blind and 5 blindfolded participants.
- Statistical inferences.
- Conclusions.

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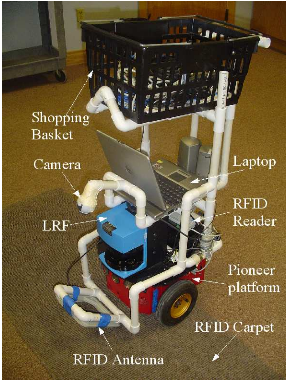
RoboCart Background: Base



Modified Pioneer 2DX Base.

RoboCart Background: RFID Strips

RFID Strips.

RoboCart Background: Placement of RFID Strips

Placement of RFID Strips.

RoboCart Background: HRI

HRI: Characters In, Synthetic Speech Out.

RoboCart Background: Product Search

Modified Barcode Reader.

Shopping Task Analysis

1. *Select a product* (*Shopper*).
2. Navigate to the shelf (*Robot*).
3. Retrieve the product from the shelf (*Shopper & Robot*).
4. Put the product into the cart (*Shopper & Robot*).
5. Repeat steps 1-4 as necessary.
6. Navigate to a cash register (*Robot*).
7. Unload and Pay (*Shopper*).
8. Navigate to the store exit (*Robot*).

Blind Communication Modalities

1. **Browsing**: Key events in, speech out.
2. **Speech**: Speech in, speech out.
3. **Typing**: Characters in, speech out.

Product Selection Research Hypotheses

1. **Hypothesis 1**: *Blind participants perform significantly more slowly than sighted, blindfolded participants.*
2. **Hypothesis 2**: *Browsing is significantly slower than typing.*
3. **Hypothesis 3**: *Browsing is significantly slower than speech.*
4. **Hypothesis 4**: *Typing and speech are significantly different.*

Product Selection Algorithm

1. Hierarchical product arrangement.
2. Automatic string completion.
3. Continuous background search.
4. Seamless switching from typing to browsing.

Experiments

1. Three independent variables: MODALITY, CONDITION (BLIND VS. SIGHTED), PARTICIPANT.
2. One dependent variable: TIME.
3. Two basic questions:
   - To what extent does TIME depend on MODALITY?
   - To what extent does TIME depend on CONDITION?

Experiments

1. **Participants**: 5 blind, 5 sighted, all computer literate.
2. **Age Range**: 17 to 32.
3. **Materials**: A database of 11,147 household items available at *www.householdproducts.nlm.nih.gov*.
4. **Settings**: Laboratory.
5. **Procedure**:
   - 20 minute tutorial;
   - Session 1: Selection of 10 random products with 3 modalities;
   - Session 2: Selection of 10 random products with typing and speech.
   - Administration of NASA-TLX to each participant.

Statistical Inferences: SAS ANOVA Summary

1. There are significant differences among the 3 modalities.
2. There are significant differences among the 2 conditions.
3. There are significant differences among the 10 participants.

Statistical Inferences: Probing Deeper

1. There are significant differences among the 3 modalities.
2. The differences can be due to two possible interactions: 1) MODALITY/CONDITION; 2) MODALITY/PARTICIPANT.
3. Both interactions are not significant.
4. **Plausible Inference**: TIME appears to depend on the inherent nature of MODALITY and does not appear to depend either on CONDITION or PARTICIPANT.

Statistical Inferences: Probing Deeper

1. Blind participant 5 is an outlier.
2. If blind participant 5 is dropped, the differences within CONDITION and PARTICIPANT become insignificant.

Statistical Inferences: Probing Deeper

1. Blind took longer than sighted to complete product selection tasks.
2. But: The differences are not significant.

Statistical Inferences: Probing Deeper

1. Over repeated trials participants improved with typing significantly more than they improved with speech.
2. This improvement could be due to some learning effect or to the inherent complexity of a particular random product set.
3. The magnitudes of improvement over repeated trials were significant and in favor of typing.

NASA-TLX

Dimension/Modality	Browsing	Typing	Speech
Mental demand	45.6	35.9	13.4
Frustration	47.8	1.8	34
Overall Workload	12.88	8.33	7

Conclusions

1. Typing and speech have the same workload: 8.33 and 7, respectively.
2. Fundamental problem with typing: spelling errors.
3. Fundamental problem with speech: recognition errors.
4. Typing preserves discretion in public places.
5. **Key question**: *What will be give us robust product selection faster: reduction of the typing mental demand with continuous background spellchecking or reduction of the speech frustration level with user training*?
6. **Our conjecture**: Spellchecking :-).

Acknowledgments

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