Improving Cognition in the Elderly via Dialogue-Based Games with Teachable Robot Agents

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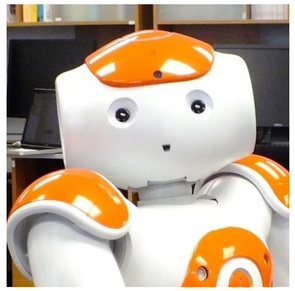
Research Question

- **Can teachable robot agents combine language learning and computer vision via an interactive dialogue-based game such as "I Spy" to improve cognitive skills in the elderly?**



Background

"I Spy" and Computer Vision

- Researchers have already created an early version of a robot designed to **learn names and attributes of various objects by playing "I Spy"** (Vogel et al., 2010)

Foreign Language Learning and the Mitigation of Cognitive Decline

- Various previous research has demonstrated that **increasing age is correlated with language-related forms of cognitive decline** including: delayed verbal recall, reduced information processing speed, speech-perception problems in real-world environments, and reduced comprehension of vocabulary and meaning (Antoniou et al., 2013).
- Furthermore, **research has shown multilingualism to be a strong predictor of cognitive ability in the elderly** (Kavé et al., 2008), and bilingual adults have also shown a slower decline in cognitive abilities with age (Bialystok, 2009)
- Multiple studies have shown that **foreign language learning leads to structural changes in the brains of young adult learners** (Stein et al., 2012; Mårtensson et al., 2012), and it follows that the process should similarly affect neural changes in the elderly
- A clear hypothesis arising from all of this prior research is that **foreign language learning could present an excellent way to delay age-related cognitive decline** (Antoniou et al., 2013)

Hypothesis and Planned Methods

Hypothesis

Foreign language learning can be combined with object recognition through an I-Spy/20 Questions game with teachable robots to exercise object recognition and speech and language processing skills and delay cognitive decline in elderly individuals.

"I Spy" Methodology

- A series of known or unknown objects will be placed in the vicinity of the robot. The robot will possess an internal memory containing information regarding each known object.
- The robot will ask questions to determine which object the human player is referring to. It will use maintain a user model to decide how questions should be asked based on the perceived knowledge level and cognitive ability of the player, with questions progressing from simple yes/no attribute-related questions to more cognitively engaging questions.
- The robot will continually add learned characteristics to a list of known information. All memory items conflicting with the learned characteristics will be eliminated, and unrecognized items will be eliminated if their observed attributes conflict with the learned characteristics as well. The robot will also reference external knowledge sources, such as the web, to help it learn.
- When the robot's memory contains only one remaining item, it will make a guess to the human. If the guess is correct (and thus, the object was already known), the robot will win. If the guess is incorrect (which means the object was not known), the robot will lose, and the human will tell the robot the correct name of the object.

A Foreign Language Twist on Traditional "I Spy"

The robot can learn to recognize objects in a foreign language, and language-immersion levels can be tailored according to the human's own foreign language skills.

Example Case – Learning French (Beginner)
At the beginner level, the only terms presented in the foreign language might be the objects themselves (la boîte, le bal, etc.).
Human: I spy something blue.
Robot: Is it round?
Human: No.
Robot: Is it square?
Human: Yes.
Robot: Can it open and close?
Human: Yes.
Robot: Is it la boîte?

Example Case – Learning French (Intermediate)
At a moderate level, attributes could also be presented in the foreign language, with yes/no responses accepted in either language.
Human: I spy something bleu.
Robot: Is it rond?
Human: No/Non.
Robot: Is it carré?
Human: Yes/Oui.
Robot: Can it ouvrir et fermer?
Human: Yes/Oui.
Robot: Is it la boîte?

Example Case – Learning French (Expert)
At the expert level, the entire dialogue might be presented in the foreign language.
Human: Je remarque quelque chose de bleu.
Robot: Il est rond?
Human: Non.
Robot: Il est carré?
Human: Oui.
Robot: Peut-il ouvrir et fermer?
Human: Oui.
Robot: Est-ce la boîte?

Expected Benefits and Importance

Technical Benefits to Machine Learning/Robot Vision

Object Recognition
- If Correct – The new case can be saved as a positive training instance.
- If Incorrect – A new object can be stored in the agent's database. The incorrect guess can be saved as a negative training instance.
- Leads to the creation of a multi-lingual knowledge base.

Cognitive Benefits to Human Players

Object Recognition
- Humans exercise object recognition skills by answering questions and describing the chosen object to the agent.
- Foreign language component promotes deeper concentration on names and attributes than native-language version of the same game.

Speech and Language Processing
- Humans exercise speech and language processing skills as they comprehend and respond to the agent's questions.

Importance

- Novel empirical results documenting the correlation between foreign language learning and cognitive decline in the elderly
- High potential for transfer to other audiences such as K-12 education or young adult learners in professional settings
- Joint contributions to NLP, robot vision, human robot interaction, and cognitive science

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