Human Computer Interfaces for Autism: Assessing the Influence of Task Assignment and Output Modalities

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ABSTRACT

Several experimental studies have shown the usefulness of computers for autism, but software design remains poorly documented. Our multidisciplinary research focuses on educational HCI for autism. We compared two domains of learning: social dialogue understanding and spatial planning, our hypothesis being that people with autism will be less skilful in the first than in the second domain. Two sets of exercises were designed for each domain: one for training purposes and the other for performance assessment before and after training. We also tested the influence of the following output modalities: text, images, speech synthesis, visual and auditory feedback. Each exercise produced log files informing on duration, number of trials and successes. So far, eight teenagers with autism have completed a 13 week training program with one session a week. First analysis of log files suggests a significant progression in dialogic understanding but not in spatial planning; nor was significant influence of output modalities found.

Author Keywords

Autism, handicap, special education, learner-centered design, computer assisted education, multimodality.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Evaluation/methodology, User-centered design*; H.1.2 [Models and Principles]: User/Machine Systems – *Human factors, Software psychology*; K.3.1 [Computers and Education]: Computer Uses in Education – *Computer-assisted instruction (CAI)*.

INTRODUCTION

Autism Syndrome

Autism is defined as a pervasive developmental disorder [1, 12]. The diagnosis relies on the following criteria: qualitative impairment in social interaction; qualitative impairment in communication; restricted, repetitive and stereotyped patterns of behavior, interests, and activities. Both verbal and non-verbal communications are altered [5]. Spoken language when it exists might not convey any social communicative exchange. Commonly, people with autism prefer engaging in repetitive and stereotyped activities rather than social activities. They seem to lack understanding of social rules and interactions. A core deficiency may be described as the inability to anticipate others' emotions and mental states [4].

Despite general common trends, there is a high inter-individual variability among people with autism. Though autism is frequently paired with intellectual retardation, the IQ (Intellectual Quotient) of a person with autism may vary from severe retardation to superior intelligence. Autism with normal or high IQ is referred to as high functioning autism or Asperger Syndrome. People with high functioning autism tend to have a well-developed vocabulary but nevertheless have profound difficulties to understand abstract social concepts.

Computer Assisted Education for Autism

Psychopathologists express growing interest in the use of computers for special education of people with autism [10]. Practitioners and parents were among the first to develop computer-based approaches for this purpose [8, 9]. Yet, no formal experimental protocols have been developed to systematically test these approaches. A few computer science projects are aimed at providing useful educational software for people with autism, as for example, language teaching tools [3, 13].

Researchers in multidisciplinary fields carried out experiments to assess the usefulness of computer education for people with autism. Moore and Calvert [7] compared vocabulary lessons provided by a teacher with computer based lessons. Results indicated better attention, motivation and vocabulary retention when the computer was used. Bernard-Optiz et al. [2] studied training with software used for social behavior education. Children had to find a solution to different scenarios involving characters in problematic social conflicts. They compared a group of children with autism and a group of children without autism. While the performances of both groups improved,

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the progression of the group without autism was steadier. Rajendran and Mitchell [11] conducted two case studies where an experimenter used a software game with an adult diagnosed with Asperger (high functioning autism) to foster adequate social responses. The software game consisted of cartoons featuring two characters. The speech and thought bubbles of each character had to be filled in by one of the two players. Yet, there was no evidence of social understanding skills improvement.

However, these studies did not specifically investigate Human Computer Interfaces (HCI) issues that would help software designers develop applications dedicated to autism. This is the goal of work in our multidisciplinary team of psychologists and computer scientists who are particularly concerned with the social understanding impairment in autism. The experiment we carried out compares learning in two domains: social dialogue understanding and spatial planning, an area in which people with autism are expected to be more skilful. Thus, computerized training in these two domains is likely to yield different outcomes. We also controlled for the impact of multimodal as compared to minimalist, task oriented interfaces. It is yet unclear if the use of multiple output modalities will improve or hinder understanding of computer exercises and we wanted to test this point.

METHOD

Participants

A group of teenagers (n=8) diagnosed with high functioning autism according to DSM IV (Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition) [1] criteria attended a workshop once a week, for 13 weeks, where they had to perform computer exercises. All of them declared having a computer at home and 6 of them declared using it at least one hour per week. One group of 3 attended the workshop during the first half of the school year and the other group of 5 attended the workshop during the second half.

Experimental Protocol

Educational software was designed for both learning domains. Our hypothesis was that people with autism would be initially less skilful in social dialogue understanding exercises than in spatial planning exercises. The subjects' skills in each learning domain were assessed before and after a training period. The first and the last sessions of the workshop were dedicated to evaluation. The other 11 sessions were used for training purposes. Both evaluation phases were based on the same sets of exercises but with different contents. These exercises were different from those used during training, though tasks were similar.

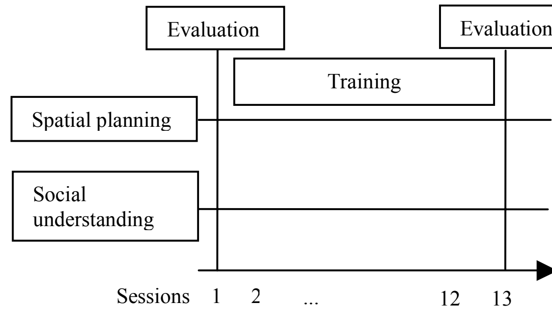

Figure 1: Experimental protocol over a period of 13 sessions: first and last are for evaluation, others are for training.

During the evaluation sessions, two distinct interfaces were tested: a minimalist interface containing only these features strictly needed to solve the exercise and a multimodal interface containing images, sounds, voice synthesis[1] and multimodal feedback. Subjects' performances were expected to be lower with the minimalist interface, as it provided fewer helpful cues to solve the exercises.

SOFTWARE DESCRIPTION

Dialogue Understanding Exercises

For social dialogue understanding, the evaluation exercise was called 'intruder' and the training exercise was called 'What to choose?'. The "What to choose?" exercise displayed a written dialogue between two characters along with three assertions about the dialogue. Two assertions were erroneous and one was true. The goal was to find the true one. The 'intruder' exercise also displayed a written dialogue between two characters, but one of the characters' responses was awkward and socially irrelevant. The goal was to find this intrusive response.

People with autism have profound difficulties to understand socially abstract expressions which convey irony or metaphor. Their interpretation is often highly literal. Howlin [5] mentions an example: "It's raining cats and dogs" might be understood as cats and dogs falling from the sky. Dialogues used in the exercises usually relied on such pragmatic difficulties.

To succeed in the exercise 'What to choose?', subjects merely needed to understand the dialogue, whereas the exercise 'intruder' required understanding the context of an erroneous dialogue and finding the irrelevant response. Hence, the evaluation exercise was based on more complex understanding skills than the one used for training.

For the 'intruder' exercise, the minimalist interface merely displayed the written dialogue. The user had to select the intrusive response by dragging the mouse over it. When the user submitted a solution, the response of the computer was written below the dialogue.

[1] IBM ViaVoice®
http://www-306.ibm.com/software/voice/viavoice/

The multimodal interface for the ‘intruder’ exercise added a synthetic voice for the dialogue and the computer’s response, an image that provided contextual cues about the dialogue and a simple click to select the intrusive response instead of dragging the mouse over it. The synthetic voice was intended to help subjects who had reading difficulties.

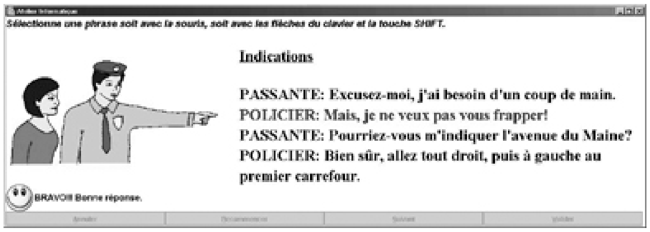

Figure 2: Example of the 'intruder' multimodal interface. The text plays on words in French. An equivalent in English is given in the footers[2].

Spatial Planning Exercises

In the spatial planning domain, the exercise used for evaluation was called ‘postman’ and the exercise used for training was called ‘labyrinth’. The later consisted of graphs where subjects had to find a path between two nodes. Graphs could contain edges that were oriented by arrows. The ‘postman’ exercise consisted of simple examples of the ‘Chinese Postman Problem’. The goal was to determine the shortest route to cover all the edges of a graph, starting and finishing on the same node.

The ‘labyrinth’ exercise required exploring the graph and planning a route that followed constraints imposed by oriented edges. The ‘postman’ exercise added extra difficulty as the circuit had to be the shortest possible. Thus, the exercise used for evaluation required more complex planning skills than the exercise used during training.

For the ‘postman’ exercise, the minimalist interface simply displayed a graph. The user had to click on the nodes to trace the route. When the user submitted a solution, the response of the computer was written below the graph. The multimodal interface added pictures and labels to illustrate each node as a specific place in town (train station, school, restaurant etc), a synthetic voice that pronounced the label of a node when it was selected and the computer’s response to a submitted solution, a visual marker for nodes adjacent to the current position.

RESULTS

Collected Data

Each evaluation exercise produced a log file that contained information on time and answers given. A subject could have up to 3 trials before the computer would give the right answer. There were 4 scenarios for the ‘intruder’ exercise and 2 scenarios for the ‘postman’ exercise. For each exercise, half of the scenarios were presented with the minimalist interface and half with the multimodal interface.

For assessment purposes, we devised three dependent variables: the number of incorrect trials (NIT), the number of correct scenarios (NCS) and the mean duration of correct scenarios (MDCS). The NIT and NCS variables both inform on success rates, but they are not equivalent because several trials can be used to make a scenario correct. The MDCS variable does not inform on success rates, but on the time taken to give the right answer.

Data Analysis

Because of the small number of subjects, a non-parametric statistical method (Wilcoxon test) was used for analysis.

Measuring Exercise Effect

Data from the evaluation of each dependent variable were compared before and after training. The NIT variable showed significant progression ($Z=-2.383$, $p=0.017$) for the ‘intruder’ exercise but not for the ‘postman’ exercise. The NCS variable showed significant progression ($Z=-2.232$, $p=0.026$) for the ‘intruder’ exercise but not for the ‘postman’ exercise. The MDCS variable did not show any significant difference before and after for either exercise.

	Intruder exercise	Postman exercise
NIT	Z=-2.383 p=0.017	Z=-0.649 p=0.516
NCS	Z=-2.232 p=0.026	Z=-0.577 p=0.564
MDCS	Z=0 p=1	Z=-0.338 p=0.735

Table 1: Results of Wilcoxon test comparison between evaluations before and after training.

Measuring Interface Effect

Data analysis of the NIT, NCS and MDCS variables before and after training showed no significant difference between the minimalist and multimodal interfaces.

	Intruder exercise		Postman exercise	
	Before	After	Before	After
NIT	Z=-0.987 p=0.323	Z=0 p=1	Z=-0.425 p=0.671	Z=-0.106 p=0.915
NCS	Z=-0.707 p=0.48	Z=-1 p=0.317	Z=0 p=1	Z=-0.577 p=0.564
MDCS	Z=-0.105 p=0.917	Z=-0.7 p=0.484	Z=-0.405 p=0.686	Z=-0.405 p=0.686

Table 2: Results of Wilcoxon test comparison between the minimalist and the multimodal interfaces before and after training.

DISCUSSION

Results indicate that subjects’ success rates were higher for the ‘intruder’ exercise after the training period. Yet,

[2] Passer-by: Excuse me, I need a hand.
Policeman: I don’t want to give you any of my hands.
Passer-by: Can you tell me where Main Avenue is?
Policeman: Of course, go straight and left after the light.

response time did not seem to vary. Therefore, training with the 'What to choose?' exercise seems to have had a positive effect on the success rate for the 'intruder' exercise, although subjects still took the same time to give a right answer. Thus, subjects were able to perform better after training on a more complex exercise than the one used for training. This demonstrates the possibility of building a training program for autism based on progressively more difficult tasks in the dialogue understanding domain.

As far as the 'postman' exercise was concerned, no evolutions were observed for success rates and performance speed. Therefore, training with the 'labyrinth' exercise did not seem to improve performances for the 'postman' exercise. Unlike the dialogue understanding domain, subjects did not perform better after training in a more complicated task than the one used during training. This difference may be explained by the fact that the computer assisted training method fostered improvements in dialogue understanding because subjects were initially less skilful in that domain. This hypothesis comforts Bernard-Optiz et al.'s views [2] that computer training is useful to teach social skills to people with autism. Yet, it does not support Rajendran and Mitchell's [11] conclusion about a possible side effect concerning gains in executive function tasks, i.e. the ability to organize and plan flexible schemes of actions. Indeed, we would have observed improvements in the 'postman' exercise that relies on organizing and planning a set of actions, but this was not the case.

Finally, we did not register the expected impact resulting from the use of multimodal interfaces for either exercise during evaluation sessions. This could be due to the increased complexity introduced by multiple simultaneous signals into the flow of the exercise. Autism is often connected with difficulties to process complex sensory stimuli originating from different modalities [6]. These difficulties have to be taken into account when designing multimodal interfaces for autism.

CONCLUSIONS AND FUTURE WORK

Our work demonstrates the usefulness of computer education in a domain where it is still underestimated: social skill training for people with autism. The study presented here is currently being extended to more subjects with autism. Detailed analysis will also include performance measurements and video annotations of subjects during training sessions which introduced novel combinations of output modalities. Moreover, we are applying the same experimental protocol to a control group of children without autism. The effects of output modalities and task assignment might be different for the control group. Thereby, we hope to collect valuable information that will be used to develop a methodology to design educational software intended for people with autism.

REFERENCES

1. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV)*. American Psychiatric Association, Washington D.C., USA, 1994.
2. Bernard-Opitz, V., Sriram, N. and Nakhoda-Sapuan, S. Enhancing Social Problem Solving in Children with Autism and Normal Children Through Computer-Assisted Instruction. *Journal of Autism and Developmental Disorders 31 (4)*, (2001), 377-384.
3. Bosseler, A. and Massaro, D.W. Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism Developmental Disorders 33 (6)*, (2003), 653-672, http://mambo.ucsc.edu/pdf/autism.pdf .
4. Frith, U. *Autism Explaining the Enigma*. Basic Blackwell, Oxford, UK, 1989.
5. Howlin, P. *Children with Autism and Asperger Syndrome: a guide for practitioners and carers*. John Wiley & Sons Ltd, Chichester, UK, 1998.
6. Minshew, N. and Goldstein, G. Autism as a disorder of complex information processing. *Mental Retardation and Developmental Disabilities Research Reviews 4 (2)*, (1998), 129-136.
7. Moore, M. and Calvert, S. Brief Report: Vocabulary Acquisition for Children with Autism: Teacher or Computer Instruction. *Journal of Autism and Developmental Disorders 30 (4)*, (2000), 359-362.
8. Moore, D.J., McGrath, P. and Thorpe, J. Computer aided learning for people with autism – a framework for research and development, *Innovations on Education and Training International 37 (3)*, (2000), 218-228.
9. Murray, D.K.C. Autism and information technology: therapy with computers. In *Autism and Learning*, David Fulton Publishers, London, UK, 1997.
10. Panyan, M.V. Computer Technology for Autistic Students. *Journal of Autism and Developmental Disorders 14 (4)*, (1984), 375-382.
11. Rajendran, G., and Mitchell, P. Computer mediated interaction in Asperger's syndrome: the Bubble Dialogue program. *Computers and Education 35*, (2000), 187-207.
12. World Health Organization *International Classification of Diseases Tenth Version (ICD-10)*. World Health Organisation, Geneva, Switzerland, 1992.
13. Tjus, T., Heimann, M. and Lundälv, M. Multimedia Enhancement of Language and Reading Skills, In *Proc. of International Congress Autism-Europe*, APPDA (2003), 278-280.