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Scaffolding – Design issues in single & collaborative virtual environments for social skills learning

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Abstract

Virtual Environments (VE's) are seen as having great potential for teaching people with autism. This paper looks at research being carried out as part of the AS Interactive project to teach social skills to adults with Asperger's Syndrome. Design issues for VE's are discussed, in particular the scaffolding required to help ensure learning objectives are met both in single user(SVE) and collaborative environments (CVE). While no firm guidelines as to when it is appropriate to move from a SVE to a CVE are offered, the factors involved in the transition from one to the other are discussed.

1. Introduction

Autism is a "spectrum" disorder, ranging from 'classic' autism with severe learning disabilities at one end, to high functioning autism (HFA) and Asperger's Syndrome (AS) at the other. People with AS can excel in certain areas academically due to having normal cognitive levels, a narrow range of interests and sometimes, obsessive behaviour. However despite having good cognitive levels and personal life skills, people with AS lack social understanding which can lead to social exclusion and failure to maintain employment due to difficulties in making friendships and communicating ideas (Strickland, 1997; Parsons et al, 2000).

Virtual Environments (VE's) and Collaborative Virtual Environments (CVE's) are seen as being particularly useful for people with autism and may provide the ideal method for social skills training (Beardon et al, 2001). The shared features between virtual and real worlds may facilitate the generalisation of skills from the former to the latter. The main benefit of VE's is that users can practice skills safely, without experiencing potentially dangerous real world consequences and the stimuli the user receives can be controlled (Parsons et al, 2000).

AS Interactive is a three-year program of research and development funded by the Shirley Foundation, which started in April 2000. The project aims to assess the potential feasibility and acceptability of VE's for adults with AS in both single user (SVE) and collaborative programs, identifying features that will be useful in social skills training and defining a suitable interface (Parsons et al, 2000; Cobb et al, in press). Specific social interaction scenarios will be built in to these environments to allow training and practice of appropriate social skills. The environments will be run on standard desktop PC systems as these are cheaper and more accessible than fully immersive headset systems and so issues raised in this paper will reflect this.

This paper looks at the work being carried out on the AS interactive project and specifically, design issues involved in making the VE programs and the differences between single and multi user environments. In single user environments, a greater level of control can be exerted, which is important when the type and amount of stimuli is a principal factor in the learning experience. In multi-user environments, however, a more rounded and realistic experience can be obtained though the lesser amount of control on what is experienced might have effects on any learning objectives. The question then becomes, when is it appropriate to use a SVE and CVE both in

terms of the experience of the user and the boundaries set by the software, and indeed just what measures within the program need to be taken to ensure that learning objectives are met.

2. Learning in Single User VE's

Currently, most learning VE's are single user environments where a person's interaction will be with objects or virtual humans that have pre-programmed attributes and responses as opposed to responses in collaborative environments by real people, which are infinitely random. Constructivist theory advocates that learning environments should support student led exploration without instructing and prescribing activity, using case-based rather than predetermined sequences (Jonassen, 1994). This shouldn't mean that users are completely free to wander around an environment and interact with anything in any order they like, as the aim of the VE's is to learn specific goals and these may be missed altogether if there is no structure. The NICE project used a VE that was unstructured and undirected which brought problems (Johnson et al, 1999), and Taylor (1996) found that children especially respond to structure and don't want to skip around the environment too much. So students should be able to choose which learning objectives they undertake at a given time and at a pace that is comfortable to them with perhaps guidance from a teacher to make sure that their learning goals are met. This approach was one successfully taken in the Virtual City project (Neale et al, 1999), where users could navigate freely around a house or choose to go outside to catch a bus to either a café or a supermarket. However once specific scenarios were undertaken, they would be guided through a number of sequences to complete a task, before moving on to either repeat the same task or trying something else. The freedom to the user is in choosing which scenario to do at any time and if they want to repeat it, e.g. in a café scenario the user can decide which table to go to and when there decide if they want to sit there or not. The structure comes in when the user has activated a certain scenario and only certain interactions or movements are appropriate at a given instance. The learning objectives for these sections take a linear approach where a sequence of events is followed one after the other. This can be shown in the model in Figure 1, where the user can only progress to the next objective by successfully completing their current one and once the scenario is complete the user has the option to repeat it.

Further choice and random elements can still be added to this model, e.g. when going to catch a bus, the user decides, first that they in fact want to go and then at what time to go. The time they choose will have a bearing on whether they can use their bus-pass or not. If they can't show their pass then the correct procedure will be to pay the exact fare in coins. So user choice and random parameters thrown up by the program will determine what appropriate behaviours are required further down the learning path. Ultimately though there is still only one appropriate action that can be taken at any given time and if this is not performed then the user will not proceed through the scenario. This can be shown in the model in Figure 2. Although different paths can be taken, the movement of flow can still effectively only go in one direction at a time, thus still a linear model.

e.g. A – User wants to eat at table and clicks on menu.
B – User selects what they want to eat and drink.
C – User pays bill.

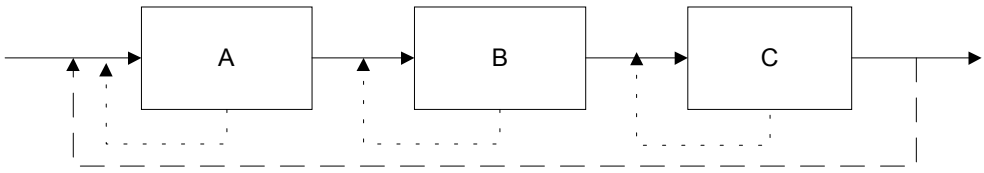

Figure 1: Linear learning model.

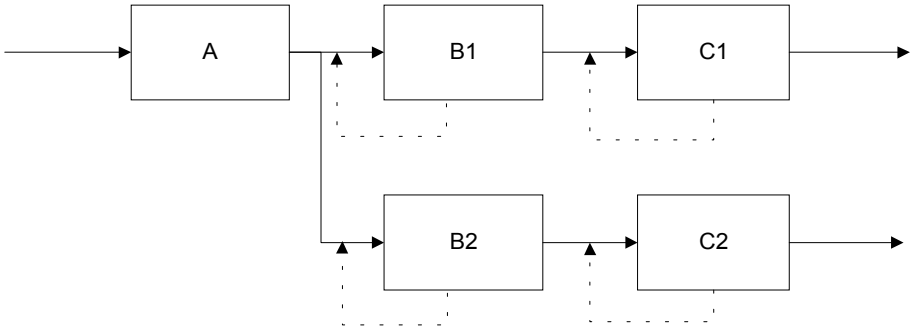

Figure 2: Split linear learning model.

This is similar to the modular organisation of games where the user can make mistakes which halt play, but in which typically the user can begin that level again (Jones, 1997). The successful games designer also rigs scenarios, so as to lead people to ideas and force them to confront and understand them (Norman, 2001). Despite these similarities there is a difference between learning software and computer games. An important piece of the enjoyment of games are the multimedia aspects, such as realistic graphics and sounds (Jones, 1997), however these could be seen as superfluous and perhaps even distracting in a learning environment. The budgets available to educational software, compared to some games companies also mean that it is not likely that many learning environments will have quite the same feeling of realism as games. Jones (1997) goes on to explain that good games seem to employ 'twitch', where a user must react quickly to circumstances to continue playing and 'strategy', which requires higher order thinking and problem solving skills. These different elements though are obviously meant to enhance the enjoyment of a game and most learning is concerned with continuing and completing the game rather than taking anything useful out from it. Learning from mistakes and past experiences can be very valuable, especially with regard to interaction in computer environments. However dissonance is easier in games because they are not constrained by content. In educational software it is more difficult to design for dissonance because ultimately we must answer to the content and its veracity. Different elements can be added to a game to make it work, while in a learning environment new elements cannot be added at the expense of the content.

3. Educating people with AS using VR

3.1 AS Issues

The AS Interactive project, as mentioned earlier, is concerned with developing social skills and social awareness for adults with AS via the use of CVE's. The Government of Saskatchewan, Special Education Unit (GSSEU), states that people with AS frequently lack understanding of social customs and may appear socially awkward, have difficulty with empathy, and misinterpret social cues. They are poor incidental social learners and need explicit instruction in social skills and students with AS may interrupt or talk over the speech of others, make irrelevant comments and have difficulty initiating and terminating conversations. Social communication problems can include standing too close, staring, abnormal body posture and failing to understand gestures and facial expressions. Their thinking tends to be rigid and they have difficulty in generalising things they've learnt into other contexts. However, they do have good memories and can learn and memorize rules about what kind of behaviour is appropriate (Dautenhahn et al, 2000), even if it is unnatural and they can't comprehend why the rule exists, but find it difficult to transfer those rules to the real world. The student with AS also finds it difficult to learn from their mistakes.

Strategies listed by GSSEU (1998) to help learning in the classroom include;

- Teaching the student how to interact through social stories, modelling, role-playing and other activity-based learning.

- Conflict resolution is managing disagreement with compromise and recognising the opinions of others, knowing not to respond with aggression or immature mechanisms.
- Appropriate opening comments, turn taking, interrupting and changing conversational topics are also taught as well as looking out for people taking advantage of them.
- Their strengths are capitalised on e.g. memory, and they are given positive praise whenever they have done something right or well.

3.2 Virtual Café

The first SVE developed as part of the AS Interactive project represented a café, as this was thought to offer a multitude of opportunities for social interaction and be a motivating environment in which to learn. The first scenario was designed to present the user with a single task, finding a seat in the café.
This environment was initially intended to test the interaction metaphors and interface to be used in teaching some of the social issues, in this case about asking appropriate questions and behaviours when looking for a place to sit down in a cafe. The metaphors are to do with the user sitting down at a table, standing up and asking questions to people. The interface consists of an area, which shows the user instructions along with an icon to hear those instruction again, an icon to listen to the overall task and a speech bubble to ask questions to the virtual people in the environment (Figure 3).

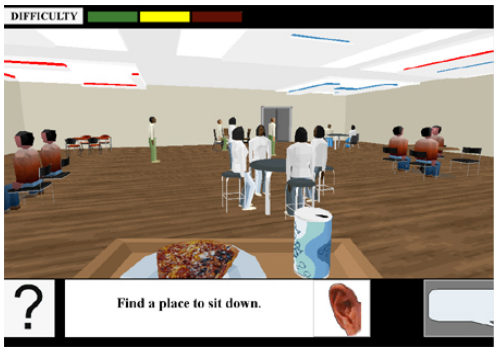

Figure 3. Café scenario interface.

The user starts the scenario at the cash register with a tray and some food and drink. They move towards a table and if there is a spare seat at it, the user's viewpoint is rotated towards the people at the table and the user is asked what should they do? The user then has initially one of three options, they can click on the table or chairs to sit down, they can click on the speech bubble icon to ask a question or they could just walk away. If the user sits down without asking they are automatically told that the seat is taken and they then have to click on the floor to stand up. If they click on the 'ask question' icon, a dialogue box then appears with a larger version of the speech bubble on it. Contained within that are questions that the user can ask (Figure 4), these being either relevant or irrelevant to the task, the latter prompting the user to try again. The questions are set out on 'radio' buttons, which means that only one can be selected at a time, and when the user exits the dialogue box, code will register which question was asked, play the sound file and then activate the appropriate response. If an appropriate question is asked, the user will be told whether the seat is available or not and this depends on a number of factors, including whether it was the first time they had asked a question or if they had previously found out the availability of the seat. If it is the first time the user has asked a question, then they will automatically be told that the seat is unavailable and this is so that the user experiences rejection even when asking a relevant question and then has to continue to try again elsewhere. Once a spare seat has been found the user then clicks on the table or chairs to sit down, the tray of food appearing on the table.

Figure 4. Ask question interface.

The nature of this environment is that the users have various options, which are either appropriate or not depending on when they are used. E.g. sitting down at a table without asking the people there if you can. This is particularly relevant in terms of trying to program in random responses from virtual humans. While it is desirable that many different responses are available, so that most possible eventualities are covered, and are presented in a random fashion so that patterns in the program are not learned, there will be a number of experiences that you want the user to have in order to learn. Therefore the user can take many different routes to completing their task, but if the process of learning involves trying specific things then they have to be 'steered' into doing them, usually by guiding their first couple of tries down a certain route before allowing them to complete the task. This makes the programming side of things much more complicated as there are lots of random elements and factors which govern a specific task depending on when, where and how it is used. The more options available, the bigger the factor of paths the user can go down and therefore more variables the program has to take into account. Therefore instead of the linear sequence of events we have a model, which can be represented as shown in Figure 5, where the route the user takes can be a complex path ending up at different places, both when going forward correctly and when making a mistake.

So the user has a number of options available to them and there will be a random response from the computer (to represent a random response from a human in the real world) and these combine to make complex paths that the user may take. To make the environment as realistic as possible, then practically an infinite amount of paths would have to be available, which is obviously not possible. As the environments get more realistic in terms of the interaction with the virtual humans, the more apparent certain restrictions or omitted behaviours become, which in turn might detract from the learning experience. This is where CVE's come in as the randomness of humans doesn't have to be programmed in as the users themselves provide this, thus overcoming the fixed response patterns in SVE's (Parsons et al, 2000). However there still must be 'rules' to the use of the environment, so that the learning objectives are met and teachers should be on hand to help in certain situations. Learning via role-play in a CVE has similar benefits to role-play in real life, but with more levels of control where a user response will automatically effect what happens in a scenario. It also excludes any undesirable effects of training in a real world situation e.g. disturbing people in a café by asking lots of questions.

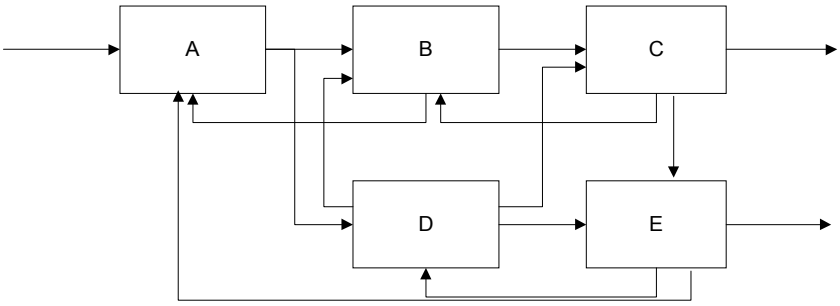

Figure 5. Complex learning model

4. CVE's and Social Learning Issues

CVE's are where more than one person interacts with the same environment and with each other. Communication takes place on a client-server model, where the environment is stored on a server, which communicates with the different user's machines (clients). These clients can be in the same room or building as each other, connected over a local intranet, or they could be on opposite sides of the world, connected over the Internet. There are obviously many issues with CVE's being connected over the Internet in terms of performance, but this paper will assume systems are being run locally on an intranet.

Collaborative learning has been shown to be consistently superior to traditional classroom lectures in both effectiveness and satisfaction (Smith et al, 1999). There are already many teaching strategies for people with AS which involve collaboration, using activity based learning where possible and encouraging cooperative games (GSSEU, 1998). This follows the constructivist learning principles mentioned earlier and when looking at learning in a social context, then this is especially true as it will involve verbal interaction, collective decision making, peer teaching and conflict resolution (Roussos et al, 1999).

If everyone using the system is in the same place, then why use a VR system, why not just use roleplay? Charitos et al (2000), state that VR systems are good for teaching people autism as;

- Complexity of scene can be controlled.
- Successive & controlled changes made for generalisation.
- More forgiving – people can make mistakes.
- Thought patterns are mainly visual and auditory.
- Autistic people like to go at their own pace (speed of presentation important).

Also due to a computer screens small area of focus, external events can be more easily ignored and in terms of accessibility, many people with autism are comfortable using standard computer hardware (National Autistic Society, 2001). CVE's can be tailored to individual needs/abilities and offer non face-to-face communication with control over verbal and non verbal features offering a stable environment, while maintaining group cohesion (Parsons et al, 2000; Smith et al, 1999). The fact that there is no face-to-face collaboration is important, as while it presents problems to the wider community in terms of how people view their peers, the ability to allow people to publicly take intellectual risks (identity hidden behind avatar) in front of their peers will be of great benefit to people with autism, who have difficulty in interacting socially (Smith et al, 1999).

For the potential of any CVE to be fully realised, an important factor to be taken into consideration is social presence. Slater (1998) broke this down to 2 contributing factors, personal and shared presence, which together was required for an effective collaborative decision making environment.

- Personal presence is related to the sense of being in a virtual space as the individuals state of mind and his acts in the environment.
- Shared presence is related with the perception of others being in same environment and the group behaviour.

Riva (1999) states that the social context in which the VR experience occurs plays a crucial role. The context can be conceptual as well as physical as users perceive situations using cultural models and this context itself is unstable as the cultural models used are constantly modified by the users actions and choices. So in other words, we have to be careful when creating the VE to take into consideration a person with AS's perception of what is occurring and how any learning effects at one level will affect their learning at the next.

5. Software Development Issues

5.1 Appropriate use of environments

Both single user and collaborative environments have their strengths and weaknesses as learning tools as discussed earlier. So when should one be used instead of the other and what measures need to be taken to make sure the full potential of each is realised in a learning context.

As mentioned earlier, single user environments offer greater control over what the user experiences. Therefore they are best utilised when specific tasks have to be undertaken with a high control over stimuli presented to the user. This would be most suited to a novice user where novice indicates either somebody who has no experience in using VE's, are learning to use the interface, are learning new interaction metaphors or are in the earlier stages of a learning process. The amount of interaction with other virtual humans required would also have to be at a minimum as there are only a small number of responses that can be programmed in while maintaining control over the learner experience and therefore learning. Neale et al (1999) state that learning environments complexity of tasks should be increased to the levels experienced in the real world. So for each overall learning objective, we have to break down the tasks to a very basic, controlled level and then introduce more and more stimuli and choice as the users ability increases. So for example, in the AS Interactive project, while the overall aim is to have users collaborating in a social learning context, they should first use an environment that gets them used to the metaphors of sitting down, standing up, asking questions etc, and then exposing them to incremental learning objectives that will eventually combine to form a fully collaborative social environment. The initial sequence of learning tasks would most likely follow the linear model in Figure 1, progressing to the complex one shown in Figure 5. In the AS Café SVE, after learning the metaphors, the easiest level will be where all the seats and tables are empty, so the user will not have anyone to ask a question to and anywhere they sit is OK. The level of difficulty is then increased by adding more people and making less seats available, increasing the likelihood that they have to ask someone a question and explore. The difficulty can then be increased still further, by having the people move around, instead of standing still talking to each other, and increasing noise levels or other distractions. As the amount of stimuli and responses gets more complex then it will become necessary to introduce users together in a CVE.

The number of people collaborating in the environment will largely depend on the learning scenarios, although the number should not be too large, as this will have a bearing on the complexity of the program in recognising states of functionality as well as the ability of maintaining some structure and coherence both in the program and in the classroom setting. In user trials anymore than 4 – 6 people would cause problems and it is envisaged that most scenarios would start with just 2 or 3 users inclusive of the teacher or facilitator. The nature of CVE's means that the user will have totally different experiences each time they use the software and if it is desirable that certain elements are achieved in order to learn, then the program has to guide the user in that direction without it being obvious that they are being led that way. So the system will generate a set of circumstances that when taken into consideration by the user will prompt an appropriate action at that time and CVE's can then be tailored to an individual's needs/abilities (Parsons et al, 2000) so that they can progress at their own pace.

5.2 Interface Solutions

Most CVE learning for people with AS should include role playing in the context of a social story. Taking on different roles will enable the student to more quickly experience the different possibilities and consequences of the actions they take. A large part of the CVE learning will be the 'communication' between the users. This communication could take the form of text being typed at each terminal and being displayed under each user's avatar or it could be verbal, through talking and listening to each other through a headphone set. If using a headphone set then the earphones should be stereo with one earphone for listening to what other people are saying while the other has sounds occurring in the environment (Smith et al, 1999). This would overcome difficulties of the user's speech and important environment sound elements interfering with each other. It should be noted however that when using sounds in environments for autistics that 'extra' sounds to enhance the environment should be avoided as this will distract and confuse the user (Charitos et al, 2000). The environments should also encourage constructive discussion between the users to talk about ideas and not focus on talking to each other solely for the purpose of completing a task (Johnson et al, 1999).

This is where teachers can have an important role. As discussed earlier, CVE's can be quite complex in terms of trying to predict all the possible behaviours and responses that will

need to be programmed. So instead, only the main factors governing the learning should be included and anything that is more 'open ended' can be discussed with the help of the teacher who can guide the students and get them to talk about what they are doing (Edelson et al, 1996). The teacher therefore becomes a 'privileged' member of the knowledge building group, one who creates an intellectually stimulating climate, models learning and problem solving activities, asks provoking questions and provides support through coaching and scaffolding. The CVE therefore must be built as a tool, which can fit into existing teaching strategies as well as offering something new (De Corte, 1993). This strategy is also advocated by Bowmen et al (1999), who state that it is dangerous to solely rely on experiences for learning as incorrect mental models can arise logically and that VE's can provide an important first step in understanding, but other knowledge and teaching are necessary for complete comprehension.

Another form of communication in the CVE is through the 'body language' of the avatars. Previously, strengths of collaborative systems have been verbal or text based communication, while action based communication performed by the user's avatar is limited. This is not so bad when using the environment for people with AS, who have difficulty in understanding expression of emotions, motives, beliefs and intentions and a failure to understand gestures and facial expressions (Charitos et al, 2000 & GSSEU). Cuddihy & Walters, (2000) state that users should be aware of other users and their work, allow a user to see what others are focussing on and convey a sense of users current activity, which increases social presence. While these features are important in helping the users communicate with each other, many of them are the issues which we are trying to teach people with AS in the first place. Therefore the program will have to be able to communicate to users in a way which conveys meaning relevantly and at the same time gradually present action based communication to the user in a controlled manner which aids the user in learning these features. A possible way is to present users meanings by images, which are understood by the student with AS. Symbol cards have been very useful in teaching people with autism and the TEACCH program has incorporated such visual representations (Charitos et al, 2000). Images are metaphors for concepts and they provide an alternate reality, which is simultaneously concrete in structure and analogic in representation (Riva, 1999). So the user can be provided with visual queues to understand the other users behaviour and gradually replace these metaphors with hopefully more realistic human behaviours in the avatars in order to transfer the meaning.

Another problem in communicating meaning between users or seeing what actions they are taking is that a person will actually see quickly enough what the other users are doing. People can spend too long orientating their avatars and miss what is happening. So while freedom of movement to explore is important, it can take away for collaborative tasks, which involve users manipulating an object within the environment or social activities (Cuddihy & Walters, 2000). This means that under certain conditions the program will have to automatically orientate users so that they are automatically facing the right way to receive relevant information.

As well as being able to facilitate good communication between users, there are a number of other factors that CVE's should conform to if they are to be seen as 'usable'. The system has to be able to answer the following questions positively. Can users accomplish the tasks they accept? Can they acquire the necessary information? Do they have the necessary control? Can they correctly sequence their subtasks? (Riva, 1999) The program should allow users to have some idea about what the VR system expects and can handle and conversely the computer needs to know the person's goals and behaviours (Riva, 1999). In terms of learning environments the system should help learners treat knowledge as an object to be discussed, yield perceptible progress and help learners see how they contribute to a group's knowledge.

Cuddihy & Walters (2000) proposed that appropriate interfaces to VE's should be dynamically constructed depending on what actions were available to the user at that time as a way of solving the problems mentioned above. Previously, many interfaces consisted of action panels, which present a palette of graphical buttons for which the avatar can perform. This action panel metaphor is context independent so the user would perform the action they chose no matter their current

situation, where only the consequences of the user's actions would be dependent on their situation. However this can be limited and does not help the user know what actions are appropriate at any given time and to what objects they can effect. So instead, embodied activity would be presented dynamically to the user at an object level as opposed to the scene level. For instance if a user wants to wave at someone the icon to wave will only appear if there is someone else in the vicinity. When pressed a list of people that can be waved to is shown. When the user selects a person their avatar will automatically rotate to face the user they are waving to, thus overcoming the navigation problems mentioned earlier. An example of a user interacting with an object would be if they pressed 'pickup' and then a list of objects *near* to the user which *can* be picked up is shown, or conversely the object is clicked on and a list of possible actions that can be performed on it appears. This type of interface then helps the user to know what they are capable of at any time thus reducing confusion and the number of errors made.

In terms of people with AS learning social behaviours, however errors do need to be made to support the learning. Therefore again, a balance has to be made between allowing the user to make errors and clearly showing what options are available at any given time. In the AS Café scenario, the user is free to move where they like, however as soon as they are close to a table that has an available seat, the user will be automatically rotated to face the table and asked what they want to do. They can then choose to proceed with trying to sit at that table or can move away elsewhere. As the user has to be close enough to a table group to interact with it, they will be told to move closer if clicking on objects which are too far away.

6. Conclusions

In the environment described above, the user is able to sit down or ask questions once they are close enough to a table to so. Therefore it might be desirable to more clearly show that tables or chairs are selectable when nearby and only have the speech bubble icon appear when at the table. In any case, metaphors that are learned in earlier single user levels can be added to, the options available to the user being increased as their ability increases. As these scenarios get more complex it will be imperative when using them that the user knows which of the metaphors learned earlier are available.

In many cases, when using the SVE's, the reasons as to why certain responses were given by the computer or the actions available to a user will have to be taken up by teachers monitoring the progress of the student. The teacher can use the experiences of the students in the environments to facilitate open discussions to further aid the learning. The learning tasks offered by the VE's themselves should fit into the overall teaching strategy in schools at present so that learning can be compounded on at all levels within the classroom, otherwise they will just be another gimmick that passes without delivering a positive impact. For this reason the CVE's envisaged in this project would work best over a local intranet in schools and not over the internet, not to mention the technical disadvantages discussed earlier. It would only be appropriate for some of the single user, early learning scenarios, to be distributed over a wider network, to be used as a trainer for the later, more important, CVE's.

The overall social learning goals should be broken down into their composite subtasks, increasing the stimuli and options to the user as scenarios are built upon. These issues learned in the SVE's will get increasingly more complex until such a time that CVE's, become appropriate. The decision as to what iteration of the learning program to use a CVE should be assessed at each design phase. This will largely depend on the diversification of responses possible for any given single action, the amount of programming resources available and the number of 'people' involved in a learning scenario. The AS interactive project will aim to explore the issues involved in the transition of moving between single user and collaborative environments especially within the practical setting of teaching in a classroom. Some initial findings with regard to using the SVE in a practical setting can be found in Kerr et al (2002).

References

1. Attwood, T. and Gray, C. Understanding and Teaching Friendship skills, *www.tonyattwood.com/paper3.htm,* (visited December 2001)

2. Bowman, D.A., Hodges, L.F., Allison, D. & Wineman, J. The Educational Value of an Information-Rich Virtual Environment. *Presence*, **8**(3), 317-331, 1999

3. Beardon, L., Parsons, S. and Neale, H. An interdisciplinary approach to investigating the use of virtual reality environments for people with Asperger Syndrome. *Educational and Child Psychology*, **18**(2): 53-62, 2001.

4. Cobb, S., Beardon, L., Eastgate, R., Glover, T., Kerr, S., Neale, H., Parsons, S., Benford, S., Hopkins, E., Mitchell, P., Reynard, G., and Wilson, J.R. Applied Virtual Environments to support learning of Social Interaction Skills in users with Asperger's Syndrome, to appear in *Digital Creativity,* Vol. **13**(1) (in press, 2002).

5. Charitos, D., Karadanos, G., Sereti, E., Triantafillou, S., Koukouvinou, S. & Martakos, D. Employing virtual reality for aiding the organisation of autistic children behaviour in everyday tasks. In P. Sharkey, A Cesarani, L Pugnetti & A Rizzo (Eds) *3rd ICDVRAT, Sardinia Italy*; University of Reading, 147-152, 2000.

6. Cuddihy, E. and Walters, D. Embodied Interactions in Social Environments, *Collaborative Virtual Environments 2000*, San Francisco, CA, 181-188, 2000.

7. Dautenhahn, K. Design issues on interactive environments for children with autism. In P. Sharkey, A Cesarani, L Pugnetti & A Rizzo (Eds) *3rd ICDVRAT, Sardinia Italy*; University of Reading, 153-161, 2000.

8. De Corte, E. Psychological Aspects of Changes In Learning Supported by Informatics, In Johnson, D. C., and Samways, B. (Eds.). *Informatics and Changes in Learning* 37-47 Conference on Informatics and Changes in Learning. Gmunden, Austria 7-11 June, 1993. Amsterdam: North-Holland.

9. Dede, C. The Evolution of Constructivist Learning Environments: Immersion in Distributed, Virtual Worlds. In B. Wilson (Ed) *Constructivist Learning Environments,* 165-175. New Jersey: Educational Technology, 1996.

10. Draper, S.W., Brown, M.I., Henderson, F.P. and McAteer, E. Integrative Evaluation: An Emerging Role For Classroom Studies of CAL, *Computers Education*, **26** (1-3), 17-32, 1996.

11. Edelson, D.C., Pea, R.D. and Gomez, L. Constructivism in the Collaboratory. In B. Wilson (Ed) *Constructivist Learning Environments,* 151-164. New Jersey: Educational Technology, 1996.

12. Government of Saskatchewan Special Education Unit Educating The Student With Asperger Syndrome, 1998, *www.sasked.gov.sk.ca/k/pecs/se/docs/autism/educate.html* (visited December 2001)

13. Johnson, A, Moher, T., Ohlsson, S. and Gillingham, M. The Round Earth Project: Deep Learning in a Collaborative Virtual World. *VRAIS99,* 1999. *www.evl.uic.edu/aej/vrais99/vrais99.html* (visited September 2001)

14. Jonassen, D. Thinking technology: Towards a constructivist design model. *Educational Technology,* **34**(4), 34-37, 1994.

15. Jones, M.G., Learning to Play; Playing to Learn: Lessons learned from computer games, 1997, *http://intro.base.org/docs/mjgames/* (visited March 2002)

16. Kerr, S.J., Neale, H.R. and Cobb, S.V.G. Virtual Environments for Social Skills Training: The importance of scaffolding in practice. (Accepted) *ASSETS, Edinburgh August 2002. ACM.*

17. The National Autistic Society, Computer applications for people with autism Factsheet. *www.oneworld.org/autism_uk/factsheet/computers.pdf* (visited December 2001)

18. Neale, H.R., Brown, D.J., Cobb, S.V.G., and Wilson, J.R. Structured Evaluation of Virtual Environments for Special-Needs Education, *Presence*, **8**(3), 264-282, 1999.

19. Norman, D.A., Learning from the Success of Computer Games, 2001. *www.jnd.org/dn.mss/ ComputerGames.html* (visited March 2002)

20. Parsons, S., Beardon, L., Neale, H.R., Reynard, G., Eastgate, R., Wilson, J.R., Cobb, S.V.G., Benford, S.D., Mitchell, P. and Hopkins, E. Development of social skills amongst adults with Asperger's Syndrome using virtual environments: the 'AS Interactive' project. In P. Sharkey, A Cesarani, L Pugnetti & A Rizzo (Eds) *3rd ICDVRAT, Sardinia Italy*; University of Reading, 163-170, 2000.

21. Quinn, C.N. Designing educational computer games*, Computer Science & Technology*, **59**, 45-57, 1994.

22. Riva, G. From Technology to Communication: Psycho-social Issues in Developing Virtual Environments, *Journal of Visual Languages,* **10**, 87-97, 1999.

23. Romano, D.M., Brna, P. and Self, J.A. Collaborative Decision-Making and Presence in Shared Dynamic Virtual Environments, *Short paper presented at Presence in Shared Virtual Evironments Workshop,* 10 - 11 June 1998*, http://cbl.leeds.ac.uk/~daniela/Collaborative_DM_and_Presence.html* (visited September 2001)

24. Roussos, M., Johnson, A., Moher, T., Leigh, J., Vasilakis, C. and Barnes, C. Learning and Building Together in an Immersive Virtual World, *Presence*, **8** (3), 247-263, 1999.

25. Smith, R.B., Sipusic, M.J. and Pannoni, R.L. Experiments Comparing Face-to-Face with Virtual Collaborative Learning, In *Proceedings of the Computer Support for Collaborative Learning (CSCL) 1999 Conference,* C. Hoadley & J. Roschelle (Eds.) Dec. 12-15, Stanford University, Palo Alto, California. Mahwah, NJ: Lawrence Erlbaum Associates, 1999.

26. Slater, M., Usoh, M., Benford, S., Snowdon, D., Brown, C., Rodden, T., Smith, G., Wilbur, S. Distributed Extensible Virtual Reality Laborartory (DEVRL). In Goebel, M., Slavik, P. and van Wijk, J.J. (Eds). *Virtual Environments and Scientific Visualisation '96*, Springer Computer Science, 137-148, 1996.

27. Strickland, D. Virtual reality for the treatment of autism. *Virtual Reality in Neuro-Psycho-Physiology,* 81-86, 1997.

28. Taylor, J. Moving into Multimedia: Issues for Teaching and Learning, *Innovations in Education & Training International*, **33**(1), 22-29, 1996.