CuttingGame: A Computer Game to Assess & Train The Visual-Motor Integration Ability for Preschool Children with Autism

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ABSTRACT
In this paper, we describe the design and implementation of CuttingGame, a computer game designed to train, record, and evaluate the visual-motor abilities of children. The game also integrates recorded data to assist in retrospective analysis. Our system consists of a desktop personal computer, a pen tablet, evaluation software, and game software designed to provide training and recording functionality. This paper discusses our user study and the initial results of a trial of this game designed for preschool children with autism.

Keywords
Visual-Motor Integration, Children, Game, Autism

INTRODUCTION
One well-established goal of public health officials has been the early detection of developmental delays. In order to do this they often use an assessment of Visual-motor integration in children. Visual-motor integration is the ability to coordinate motor movement with visual stimuli and it is something with which children with autism or developmental delay have noticeable difficulty. Traditional treatment activities, which have the students clipping and pasting paper, are designed and facilitated by therapists and require professionals to observe or video-tape sessions for further analysis. Many appointments need to be scheduled to accommodate all the children who need them, and this often means that each child has a relatively short time to receive treatment. Unfortunately, results from activities and standardized tests need professionals, like therapists, to evaluate and grade them manually, and this can be a laborious and inaccurate task. The time-consuming human-resource requirement makes this more extensive training/evaluation (proven to be effective in the treatment of developmental delay) almost impossible.

Another factor in our thought process was the fact that current research findings demonstrate that people with autism enjoy interacting with computers [1] and robots [2], because of their predictable characteristics. For example, PETS [3][4] is a popular robot that mimics children's posture. Therapists use it as a means to involve children in story-telling activities. SIDES [5], a four-player cooperative tabletop computer game, helps adolescents with Asperger's Syndrome practice group work skills. Picard *et al*. [6] even developed a system to help autistic children learn to recognize affective information by synthesizing interactive social situations.

These examples demonstrate the power and possibility of involving computer technology in a variety of treatments for children with autism or Asperger's Syndrome. However, our work looks at this idea from a slightly different angle. Inspired originally by simple clipping and pasting, we designed a computer game, called CuttingGame, to serve as a standardized test in the assessment of the visual-motor integration abilities of children. By making the test a game, we created a playful experience that is also a complete system. The game both assesses and trains children in visual-motor integration and does so in a natural and enjoyable way.

DESIGN REQUIREMENTS
According to the developmental milestones suggested by the National Dissemination Center for Children with Disabilities (NICHCY) [7], preschool children learn to control their fine muscle movement around the ages of 3-5 years old. We designed CuttingGame to be a computer-based activity that requires no literacy and mimics the traditional clipping and pasting therapy games that occupational therapists use to train children with visual-motor integration difficulty.

On top of a visual-motor integration disability, some children with autism have informational process biases that place emphasis on visualizing what is termed 'local' in precedence over what is considered 'global' information. This makes them unable to recognize the parts of a picture as elements of a unified whole. We designed our algorithm to support the effect of clipping a larger picture into multiple pieces, so children who fail to recognize this as a whole entity will end up with multiple fragments. We use this effect as feedback to help identify children with this disability and assist them in the perception of the parts of a picture as a complete entity.

In order to be successful we identified several important aspects of iterative design. First, as our target users are preschool children, they are almost illiterate and know few words other than their own name. Obviously, to increase usability, words had to be avoided in the user interface. Also, because of their lack of experience, it is difficult for children to understand the notion of a 3D virtual world, or indeed for them to perform tasks in that world. This is especially true for children with a visual-motor integration disability. Therefore, we used simple contexts and ideas with which children are familiar. Then, for children with a visual-motor integration disability, we aimed to design training software that enabled extensive training at home without the need for a therapist present. Because of this, the procedure for setup and the software needed to be as simple as possible. In addition, it was our hope that the software would provide not only the functionality of training but also a playful experience. In short, the game should be fun, should support creativity exploration, and have an integrated reward mechanism as an incentive for children to participate in repeated training sessions.

GAME DESIGN

We used Adobe Flash [8] to design CuttingGame, which preserves cross-platform characteristics and makes it easy to deploy on Internet. The only hardware a target child's family needs to be equipped with is a personal computer or laptop, and a pen tablet with stylus. The reason we chose the pen tablet with stylus, rather than the mouse and track ball, is that the mouse and track ball cannot accurately and steadily control the cursor. As the idea is to evaluate the visual-motor integration aptitude of children according to their ability to control the cursor, it was imperative to use an input device that could more accurately reflect fine motor skills.

Content presented in the CuttingGame is categorized into three "books": figures, objects, and scenes. There are 8 figures in the figure book: two boys, two girls, one man, one woman, one old man, and one old woman. There are 46 objects in the object book including clothes, food, etc. Scenes have been selected to be places familiar for children as such as the kitchen, bedroom, backyard, park, or playground.

Typical game play flow may be:

- Select a page that contains the figure or object you want.
- Clip the figure or object from that page.
- Move the clipping to the drawer.
- Select the scene you want as the background to your artwork.
- Paste the clipping on the scene.
- Adjust the clipping's location and size into the way you like.
- Color the clipping.

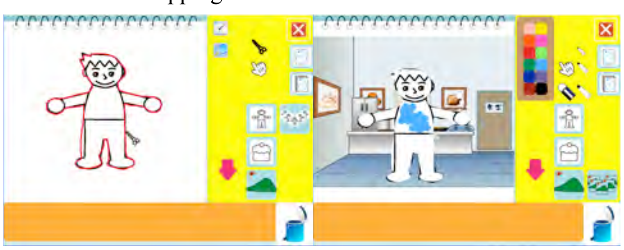

Figure 1. Two phases: clipping, then drawing

Of course it is very important to make sure children are compelled to use the training tasks embedded in CuttingGame. Unlike clipping, which requires children to follow the border of the picture in each page, drawing is a free-style activity. There are thousands of ways to fill a region with color. However, if a child was able to color a picture without clipping, our game would lose some training functionality. To tackle this problem, we designed our game as a two-phase activity: first clipping, then drawing. (Figure 1) We also add a locking mechanism to enforce the rule that children will not be allowed to color the picture until they clip it and put it in the scene they have selected.

There are three virtual tools in the game: a pair of scissors, a pen, and an eraser. First the scissors are used to clip the picture and then the pen and eraser can be employed to color the clipping. As mentioned before, because there is no constraint on how the figures are colored, we do not grade children's performance based on the result of the color of the drawings. However, the act of drawing also requires children to control their stylus carefully if they want the paintings to be nicely and neatly colored (which is encouraged). By allowing the functionality of drawing on both clippings and the scene we can assess children further. If they are not as adept at controlling their stylus they will invariably color unexpected areas of the scene. Then the eraser serves as a tool to compensate for the errors children make and clear unwanted "paint" from the scene or figure. Controlling the eraser also requires children to use their stylus carefully.

In addition to the tools that mimic those in the real world, we provide two other tools to enrich game play: refreshing and resizing. By refreshing the content on the page, children get a new clean copy that can be used for another session of training. The main advantage of resizing is so children can alter their experience in another creative way when constructing their artwork.

Accompanying the game is a manual we designed to teach both children and parents how to explore all the possibilities of CuttingGame. The manual contains descriptions of each button and shows completed scenarios with screenshots that demonstrate all the functionalities of CuttingGame. When children finish the training exercise, CuttingGame stores the artwork onto a hard disk as a JPEG file. The ability to admire these JPEG files later serves as an incentive for children to repeatedly play the game (and therefore continue training). An assessor can also observe a pattern of performance through this artwork.

EVALUATION SYSTEM

Based on the ideas of the Southern California Motor Accuracy Test-Revised (MAC-R) [9] and the Visual Motor Test of Integration (VMI) [10], we designed our evaluation system to measure the performance of children when deviating from a border during a clipping action. In addition to a locus that consists of the coordinates of clipping, we also record which page children cut, the starting time stamp of the game, time stamp of each movement, and the ending time stamp of game play. Then, based on this information, we built the two major components of the evaluation system: CuttingAnalyzer and CuttingSimulator. CuttingAnalyzer automatically assesses performance based on a record of game play using output statistics for professionals. CuttingSimulator is a tool for professionals so that they can review a child's performance by simulating the game play process. We even developed the electronic version of an automatic evaluation system in order to assess performance and avoid human error or wasted time for professionals. Most importantly, we believe that our automatic evaluation system can cover all of the requirements from training to evaluation, giving it the potential to serve as a standardized test.

USER STUDY AND RESULT

The families of seven children with autism and visual-motor integration disabilities were recruited to install CuttingGame in their home. Before using CuttingGame training at home, children took MAC-R, and VMI as pretests to determine their baseline knowledge and preparedness for further training. Then children and parents were given a tutorial of how to play

CuttingGame. During the first month children played once a day and then were asked to take the two standardized test at the end of each week. After the first month of training, children stopped playing CuttingGame for a month. When this month of no training concluded, a follow-up was conducted to assess whether the effect of training was retained.

Initial analysis shows that 6 of 7 children made progress after the training while the other child did not train according to the schedule. Results showed that children benefited from the process and that the deviation of clipping action from the border of pictures decreased gradually. The results of MAC-R and VMI are still under analysis, and they will be compared to results from CuttingGame to see if our system can serve as a standardized test.

Discussion

Feedback from parents shows that children did not consider CuttingGame as training or testing tool, but as a fun game that they actively asked to play everyday. One mother mentioned that her son enthusiastically clipped all the pictures during the last few days of the training month because he was informed that the training would stop for the following month. Also, several children repeatedly asked us if they could keep CuttingGame after the study.

As previously stated, we designed the game manual as a reference guide for parents and children. During the training, we found one child who colored the clothes with a single color the first week, but then drew lines and patterns on the clothes of the figures the following week. The child told us that he learned to color the clothes this way from the examples presented in our manual. This was not something we expected to be one of the functionalities of the manual and we were gratified by this unanticipated benefit.

Figure 2. Child's artwork

After children took their weekly test, we gave them printouts of the artwork (Figure 2) they had created the previous week. These made them extremely excited about their work. We found that these printouts not only served as incentives for them to play again, but also created a chance for each child to view the artwork of the others and then to discuss the story behind his or her creation. This gave the children a chance to interact, to share, and to consider (or re-consider) their own style and technique of painting. The artwork also became a platform for each family to relate experiences specific to their life, such as events from work, school, or in the home. We consider this opportunity to enhance the relationships inside the family unit to be the most valuable extra benefit of CuttingGame.

Ultimately, however, there are still some difficulties to the process. One issue is that the stylus is not really a pair of scissors. Although both require specific types of coordination, the way the muscles work are different for each. This makes the similarity of the training effect questionable. Also, in a typical clipping and pasting activity the location and orientation of papers are adjustable. On the other hand, the simulated pen tablet is relatively fixed on the table. This alters the experience somewhat and may be another factor that makes assessment difficult. Another difference to consider is that children playing CuttingGame have to look at a screen rather than at paper in their hand. The virtual nature of the activity might add a level of complexity. Then, when it comes to investigating results, the information that CuttingGame records is inherently less detailed than the information that comes from professionals observing children playing clipping and pasting games. This decreases an ability to assess their disability purely through the game. There was also the question of uniform progress. We discovered that one of the children always selected the figures that were easier to clip which lowered the effectiveness of the training as an enhancement tool. To combat this, we have considered incorporating the idea of a difficulty control in the game that will arrange and present the figures according to a child's progress.

Figure 3. Child ignored the figure on the page

Also, though the contents of CuttingGame are fixed, one child ignored the figure on the page. In this trial, the child treated it as a blank sheet and clipped out a piece that looked like a ship. He also ignored the scene and drew seascape on top of that scene. He then pasted the ship on the seascape to form his artwork, (Figure 3) ignoring the picture under his drawing. To solve this problem, we may simply add a white page to both the figure and scene books. Though that will have the effect of making an assessment between children more troublesome because they may clip an arbitrarily drawn figure, and the difficulty level of these will not be easily comparable. This creates a new challenge for us to balance when considering our CuttingGame as both a game and training tool.

CONCLUSION AND FUTURE WORK

In this study, we showed that it is possible to develop a computer game as both a training and testing tool. It covers all the functionalities needed (training, recording, and evaluating) to assess a child's visual-motor integration ability. The addition of designing the tool as a game, made the process of training and testing fun for the participants. Simplicity of deployment will further increase training progress by making extensive training possible without the presence of a professional. Inspired by the idea of Southern California Motor Accuracy Test-Revised (MAC-R) [9] and the Visual Motor Test of Integration (VMI) [10], the ultimate goal of CuttingGame is to serve as a standardized test. If standardized, it will become acceptable as an assessment tool and more children will gain from playing it.

Future studies may include large-scale research that recruits more participants to see if the game is useful for all kinds of children. Based on input from parents and children, we may also adopt the idea of difficulty control to better train/access children's visual-motor integration ability. We would also like to compare the results of the two current standardized tests to that of our game to get a better understanding of how our game compares as an electronic version of these assessments.

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