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Interactive Visual Schedule with Avatar Buddies for Activity Planning in Autistic Children

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Abstract. Autism spectrum disorder can greatly affect the well-being of autistic children and their family members. Visual aids, such as schedules, have been commonly used in this community for their benefits in multiple aspects. Utilizing digital technology, we presented the design of an interactive visual schedule system with avatar buddies for activity planning in autistic children. 12 pairs of participants were recruited, USE questionnaire and interviews were used for validation. The user study showed that the digital interactive system presented advantages in the perspective of usefulness, particularly in enhancing children's control over activity planning and assisting in activity completion, compared with traditional visual schedules. It demonstrated the feasibility of integrating digital technology into the field of health and highlighted the matching between the flexibility of digital technology and the personalized needs of special groups.

Keywords. autistic children, digital interactions, visual aids, avatars, buddy systems

1. Introduction

For children with autism spectrum disorder (ASD), presenting obstacles or differences in various social interaction situations is a core characteristic [1]. Comparing with interacting with other people, many studies found that they seem to have smoother interaction with computers and/or robots, and they also prefer to spend more time on them [2]. A core explanation for this phenomenon is that computer reactions are rule-based and highly predictable, and this seemingly unchanging pattern is what they like and can reduce their anxiety.

In terms of improving predictability and reducing anxiety, visual schedule is a very commonly used and evidence-based tool [3]. Benefits of using visual schedules also include improving engagement and promoting independence during tasks [4, 5]. However, traditional paper-based visual schedules are prone to damage, inconvenient to

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update, have poor flexibility, and have very limited functionality. Thus, there are plenty of technology-assisted research are developed based on traditional tools.

In this paper, we present the design of digital interactive visual schedule integrated with avatar buddies, which provide effective incentives and added fun. With the help of carers, children could use it to plan their daily activities or routines. The interactive schedule system not only serve as a tool for practicing children's organizational skills, but also motivate and drive children during activities through the companionship of animal avatars.

Using quantitative and qualitative methods, we conducted validation of the design with autistic children and their parents. Results suggested that the innovative digital interaction system has shown advantages in aspects such as increasing children's control over activity plans and assisting in activity completion. Its role in improving efficiency still needs to be further explored. Parents were generally satisfied with the system and their needs were meet during the study. This work contributes to the fields of digital technology, ASD research, healthcare for special groups, and design, with an emphasis on supporting family life of autistic children. Our design and experimental results also demonstrate the feasibility of integrating digital technology into the field of health. At the same time, the significance of matching between the flexibility of digital technology and personalized needs of special groups have also been emphasized.

2. Background

2.1. Visual Schedules

There is already a wealth of evidence on the benefits of providing visual supports for people with ASD. Visual supports, defined as "a visual display that supports the learner engaging in a desired behavior or skills independent of additional prompts" was reviewed and selected by authority as one of the twenty-eight evidence-based practices for children, youth and adults with autism [3]. Also, visual information can be processed more effectively by individuals with ASD than other types of information, such as auditory information [6]. Among all types of visual supports, visual schedules are the most common research objects in the community of individuals with ASD, other common categories of visual supports include Picture Exchange Communication System (PECS), Timers, Choice boards, etc. [7].

By using a series of symbols or objects, visual schedules usually describe the content, the location, the sequence, etc. of following activities, or steps of a single activity. "Schedules" have been included as "established interventions" by the National Autism Center for its usefulness in facilitating planning and promoting independence among students [4]. Although all visual supports may essentially rely on images and/or text to present and communicate information, visual schedules emphasize on providing predictability for users as visual structures to reduce anxiety and encourage the development of a myriad of skills [7, 8], while other supports have different focuses, such as PECS usually used with non-verbal/minimum-verbal children to promoting social-communicative skills [9].

Previous research suggested that traditional/paper-based visual schedules implemented in mainstream classrooms could help students with ASD in staying on-task and navigating through activity transitions, which are challenging for them due to their cognitive and behavioral differences [5]. However, visual schedules have been developed in digital form recently, implemented on tablets [10, 11], smartphones [12] and/or large screens [13] in different context (personal use, classrooms). Reviews suggested that computer-assisted visual schedules, as a form of technology-aided interventions, have been used successfully at home [7], and could also provide positive effects [14].

Although the application of visual schedules is very extensive, we have found that most of the schedules in research were still handmade and in the traditional way. Although DIY is the easiest accessible way to it, it often requires a certain amount of preparation time in advance. Digital schedules can easily conquer this disadvantage, but the number of schedule cases supported by technology does not match the current popularity of smart devices.

Moreover, studies and researchers were also reporting concerns on the use of technology with people with ASD [8]. The quantity and quality of related studies are limited, and this may be due to the strong contextual relevance, individualization and adaptation of these type of research objects [7]. Further research is needed for investigating not only the possible application, positive effects and the effectiveness of technology-based interventions, but also the potential negative effects on autistic people.

2.2. Avatar Buddy

Implementing "buddy system" in activities, interactions and/or designs can usually offer peer support and understanding for individuals. Peer-based instruction and intervention (PBII) is one of the proved evidence-based practices for autistic individuals which gained growing empirical support recently [3]. It requires direct input from peers whether promoting autistic children's social interactions and/or helping them with other individual goals [7].

However, as previous studies had shown that, comparing to taking to other people, autistic children tend to be more willing to talk to social robots [15]. Having difficulties communicating with other neurotypical children made them a major target group in the scope of human-computer/human-robot interaction [16].

There are plenty examples of social robots and avatar-based virtual reality systems utilized with autistic children and adolescents. A trustworthy stuffed, animal lookalike robot was developed by Smakman, Matthijs HJ, et al for supporting primary school children's well-being and reduce stress in classrooms, which can also benefit children with autism [17]. Exercise Buddy, a virtual buddy system had been designed and in use for students with autism spectrum disorder and others used in physical exercise programs [18]. Advanced intelligent designs can also be found. A virtual life coaching system called Buddy, which could be operated autonomously by children or adolescents with autism after carefully prepared by their individualized educational placement teams, is aiming at improving the emotion and mental state of autistic individuals [19]. These studies demonstrated the rationality and advantages and of implementing avatars as an alternative to peer buddy for individuals with autism. However, results from a recent review suggested that robots may not be ready yet to be effective in interventions for ASD, many of the robots were playing the role of "entertainment agent" [16]. Thus, instead of developing robots, we created several digital animal avatars as buddies for autistic children throughout the processing of carrying out tasks in our design as preliminary tryouts.

3. Design of the System

The design of the digital system is based on the traditional visual schedules, and it is designed to be used on tablets. In the designed usage scenarios, the tablet will always be placed within accessible range, serving as a visual structure where children and parents can always see, with corresponding animation effects.

After entering the system, children can directly start to create new customized schedules or select histories that had been saved by the system since last use (Fig. 1b).

Figure 1. (a) Welcome page, (b) Home page.

Creating new schedule consists of three steps: selecting activities, selecting reward, and selecting an avatar buddy (Fig. 2). A default schedule should have at least three activities, children can tap or drag the corresponding graphic symbols to the blank box to complete the schedule, and schedules with more than three activities are also feasible. Once the activities are defined, rewards can also be selected according to children's preferences, achieving a high level of autonomy over the system. Selecting avatar buddies is an important part in children's creating process and avatar buddies serve as incentives for children in the executing process.

Figure 2. Three steps of creating new schedules (in sequence).

After the avatar is selected, the system will generate a random task for the avatar which consist of the same number of activities as in the children's schedule to create a sense of companionship through the synchronized task process, with a short background story about it (Fig. 3a). Animation effects will show that the avatar is working toward designated goals and encouraging children to keep going. The work process of the avatar will only push forward when the child completes his/her tasks to maintain a consistent progress between them (Fig. 3b).

After children completing all activities planned in the schedule, a short animation of the avatar finishing its task will be played to celebrate their mutual success as an incentive for the children (Fig. 3c), similar reward method was also utilized in previous research [13].

Figma Desktop App 116.12.2 and Figma for VS Code 0.2.7 were used to develop the prototype.

Figure 3. (a) Background story and generated tasks of the avatar, (b) the avatar is making progress with the child, (c) the celebration animation.

4. Validation

To validate the usefulness of the digital system, we designed a comparative experiment using the traditional paper-based visual schedule (Fig. 4) and the interactive visual schedule as variables. In terms of the function of planning and confirming activity completion, the paper-based version of the visual schedule remains the same as the interactive one, but it does not include avatar buddies, as well as the corresponding information and interactions brought by avatar buddies during the process of activity executing.

We recruited autistic children and their parents from local institutions. A total of 12 children (11 boys and 1 girl) joined and finished the study with their parents, and informed consents have been obtained. The severity of ASD is categorized into three levels according to the levels of support required [1], level 3 represents requirements of a significant amount of support. The age of children was between 4 to 8 (mean=5.83), with none of them was rated as level 3 severity.

4.1. Measures

Quantitative measurement indicators were adopted. The usability of the system was measured from a parental perspective, since it is difficult for children with autism to provide their own feedback on the evaluation of the tools. Items from the 'usefulness' section of the USE Questionnaire [20] were adopted as measures:

- 1. It helps the child be more effective.
- 2. It helps the child be more productive.
- 3. It is useful.
- 4. It gives the child more control over the activities.

- 5. It makes the things the child needs to accomplish easier to get done.
- 6. It saves us time when we use it.
- 7. It meets our needs.
- 8. It does everything we would expect it to do.

Parents were asked about to what extent do they agree with these descriptions with a Likert scale from 1 to 5, which 5 represents the highest level of agreement. And all items are being rated positively. We also conducted short interviews with parents afterwards, with a series of open-end questions asking for more specific opinions of the system.

4.2. Procedures

The study was conducted in a separate room within the institution to avoid interference from other children and other unrelated personnel. Before the official start, the parents received a separate explanation on how to use two types of visual schedules and the experimental procedures. All possible options (both activities and rewards) for developing a schedule were fixed in this experiment to improve consistency. “Puzzle”, “doodle” and “tidy up toys” were selected as designated activities, the reward was “snack”, and for the interactive visual schedule, the bunny was the selected avatar buddy.

Each group of parents and children conducted two rounds of experiments using traditional and interactive visual schedules respectively. To reduce the impact of sequence errors on the results, the tested families were randomly divided into two groups, starting with different types of demos. The two rounds of experiments for each group of families were conducted over two days.

Children and their parents completed the entire experiment together on the desktop. Experimental demo (either the traditional one or the interactive one) was set up in advance on the table, and other needed supplies were also provided. In each round of experiments, parents will follow the same procedure: (1) Introduce the experimental demo to their children in language, guide them to use the demo to develop designated schedules. (2) Parents assist their children in executing the planned activities in sequence. After completing each activity, parents will guide their children to confirm the completion of it on the demo, and finally complete all planned activities and receive rewards. If they are using interactive visual schedule, then parents will also guide children to observe changes in the avatar buddy while executing and completing activities.

Due to children’s different levels of abilities, we did not limit the time for completing each activity. However, parents were informed that the expected completion time should be around 20 minutes for the whole process. Thus, if parents found any activity was too difficult for children to complete and had taken more than 10 minutes, it should be skipped and move on to the next one to ensure the completion of the whole process, and the activity which had been skipped would be recorded as a failure. After each round of experiment, parents will fill out the questionnaire and after the completion of two rounds, they will be briefly interviewed.

5. Results

From the perspective of task completion, the assistance provided by the digital interaction systems is relatively limited. Among three designated activities, the completion rate of the last two activities had increased(from 75% to 83.3% for “doodle” and from 75% to 91.7% for “tidy up toys”), while the first one remained unchanged (both 58.3% for “puzzle” with different schedules). By comparing the magnitude of change in the completion of the three activities, we found that the “puzzle” was the most difficult one for children, with the same completion rate for traditional and digital schedules, and a relatively observable improvement in the rate of completion for the simplest activity of “tidy up toys”. Therefore, we speculate that the digital interactive visual schedule system may only play a restricted role in assisting task completion in general, and especially for complex activities.

The results collected through the USE questionnaire provided us with some positive feedback. The rates given by parents after each round of experiments were presented in the Table 1. It can be discovered that except for the sixth item, the average rate changes of all description items are positive, indicating the overall improvement in usefulness of the digital interactive systems compared to traditional visual schedules.

The change rates of the average scores of all descriptive items are 19.1%, 37.6%, 19.6%, 34.2%, 32.7%, -28.8%, 19.3%, and 15.0%, respectively. The top item in terms of change rate was the second, however, with a highest σ^2 which suggesting the difference between different answers is too large, it may indicate that the digital interactive system was not related with children’s productivity in this scenario. The significant change rates of items 4 and 5 collectively reflected the advantages of digital interaction systems in providing enhanced children's control over activities and assisting in completing them. This inference is not entirely consistent with the conclusion drawn from the data of completion rate. However, referring to all the other descriptions with positive change rates, we believe that digital interactive systems have great potential to assist in various aspects to special groups.

Table 1. Rating results of the USE questionnaire.

Item Number	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
	T	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**
P1	3	4	2	2	4	4	3	3	3	4	4	3	4	4	3	3
P2	4	4	1	4	4	5	3	4	3	5	3	3	3	4	3	4
P3	3	3	3	4	3	4	3	5	4	4	4	2	3	4	4	4
P4	4	4	4	5	4	5	3	4	3	4	3	3	4	4	3	5
P5	3	5	2	3	4	4	3	5	3	4	4	3	4	5	3	4
P6	4	4	4	4	4	5	3	4	4	5	3	3	3	4	4	4
P7	3	4	5	1	3	4	2	3	3	4	4	3	3	3	3	3
P8	4	5	1	4	4	5	4	4	4	4	4	2	3	4	4	4

P9	5	5	2	5	4	5	3	4	4	5	5	3	4	4	4	5
P10	4	4	2	3	5	5	3	4	4	5	3	3	4	5	5	4
P11	3	5	1	3	3	4	2	3	3	4	3	1	3	3	2	3
P12	2	3	2	2	4	5	3	4	2	5	5	3	3	5	2	3
Mean	3.5	4.17	2.42	3.33	3.83	4.58	2.92	3.92	3.33	4.42	3.75	2.67	3.42	4.08	3.33	3.83
σ^2	0.58	0.47	1.58	1.39	0.31	0.24	0.24	0.41	0.39	0.24	0.52	0.39	0.24	0.41	0.72	0.47

* T=traditional visual schedule, D=digital visual schedule.

6. Reflection

We reflect on the limitations of this study as follows. Firstly, for the user sample, the quantity is relatively small, and we have not successfully recruited more girls, which may inevitably introduce bias into our results. In addition, in terms of experimental design, the diversity of activities is insufficient, and long-term and in-depth experiments are needed. The questionnaire rating results showed a negative change in the evaluation of time saving from traditional visual schedules to the digital ones. On the one hand, this may be due to the inherent drawbacks of digital interactive systems, but it may also be the result of inadequate design of the system and/or experimental processes.

Insights for system modification were collected and the system could be improved further in several aspects, such as increasing multi-platform accessibility; offering more creative ways of interactions; allowing customization for avatar characters, and smart generation on the avatars' tasks.

7. Conclusion

Through user experiments on demos, this innovative digital interaction system has shown certain advantages in terms of usability compared to traditional tools, especially in increasing children's control over activity plannings and assisting in activity completion. Parents were generally satisfied with this new design and had stated that it meets their needs in activity planning scenario. As an application practice of digital technology for special groups, our design and experimental results demonstrated the feasibility of integrating digital technology into the field of health, as well as how the flexibility of digital technology could serve the personalized needs of special groups.

References

[1] American Psychiatric Association, *Diagnostic and statistical manual of mental disorders: DSM-5*. American psychiatric association Washington, DC, 2013.

[2] Scassellati, B., How social robots will help us to diagnose, treat, and understand autism. in *Robotics research: Results of the 12th international symposium ISRR*. 2007. Springer.

[3] Steinbrenner, J.R., K. Hume, S.L. Odom, K.L. Morin, S.W. Nowell, B. Tomaszewski, S. Szendrey, N.S. McIntyre, S. Yücesoy-Özkan,M.N. Savage, Evidence-Based Practices for Children, Youth, and Young Adults with Autism, *FPG Child Development Institute* (2020).
[4] National Autism Center, Findings and conclusions: National standards project, phase 2, *Randolph, MA: National Autism Center* (2015).
[5] Macdonald, L., D. Trembath, J. Ashburner, D. Costley,D. Keen, The use of visual schedules and work systems to increase the on-task behaviour of students on the autism spectrum in mainstream classrooms, *Journal of Research in Special Educational Needs* **18** (2018), 254-266.
[6] Fage, C., C. Consel, K. Etchegoyhen, A. Amestoy, M. Bouvard, C. Mazon,H. Sauzéon, An emotion regulation app for school inclusion of children with ASD: Design principles and evaluation, *Computers & Education* **131** (2019), 1-21.
[7] Rutherford, M., J. Baxter, Z. Grayson, L. Johnston,A. O'Hare, Visual supports at home and in the community for individuals with autism spectrum disorders: A scoping review, *Autism* **24** (2020), 447-469.
[8] Glumbić, N., M. Đorđević,B. Brojčin, Autism and Digital Learning Environment, in *Digital Inclusion of Individuals with Autism Spectrum Disorder*, N. Glumbić, M. Đorđević, and B. Brojčin, Editors. 2022, Springer International Publishing: Cham. 47-74.
[9] Lerna, A., D. Esposito, M. Conson,A. Massagli, Long‐term effects of PECS on social‐communicative skills of children with autism spectrum disorders: a follow‐up study, *International Journal of Language & Communication Disorders* **49** (2014), 478-485.
[10] Spriggs, A.D., V. Knight,L. Sherrow, Talking Picture Schedules: Embedding Video Models into Visual Activity Schedules to Increase Independence for Students with ASD, *Journal of Autism and Developmental Disorders* **45** (2015), 3846-3861.
[11] Mercier, C., Measuring Cognitive Availability of Young People with Autism Using Digital Agendas, *Psychology & Psychological Research International Journal* (2019).
[12] Oliveira, M.S., C.P. Pereira, K.C. de Santana,K.O.C. Rossinholli, Autisdata: Software to Help the Development of People with ASD based on TEACCH and PECS Methodologies. in *Proceedings of the 11th International Conference on Computer Supported Education - Volume 2: CSEDU*. 2019.
[13] Cramer, M., S.H. Hirano, M. Tentori, M.T. Yeganyan,G.R. Hayes, *Classroom-based assistive technology: collective use of interactive visual schedules by students with autism*, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2011, Association for Computing Machinery: Vancouver, BC, Canada. 1–10.
[14] Sansosti, F.J., M.L. Doolan, B. Remaklus, A. Krupko,J.M. Sansosti, Computer-Assisted Interventions for Students with Autism Spectrum Disorders within School-Based Contexts: A Quantitative Meta-Analysis of Single-Subject Research, *Review Journal of Autism and Developmental Disorders* **2** (2015), 128-140.
[15] Scassellati, B., H. Admoni,M. Matarić, Robots for Use in Autism Research, *Annual Review of Biomedical Engineering* **14** (2012), 275-294.
[16] Salimi, Z., E. Jenabi,S. Bashirian, Are social robots ready yet to be used in care and therapy of autism spectrum disorder: A systematic review of randomized controlled trials, *Neuroscience & Biobehavioral Reviews* **129** (2021), 1-16.
[17] Smakman, M.H.J., D.F.P. Vanegas, K. Smit, S. Leewis, Y. Okkerse, J. Obbes, T. Uffing, M. Soliman, T. van der Krogt,L. Tönjes, A Trustworthy Robot Buddy for Primary School Children, *Multimodal Technologies and Interaction* **6** (2022), 29.
[18] Montague, M.,G. Madison, BUDDY: A Virtual Reality Based Computer System for Children with Autism Spectrum Disorders, (2017).
[19] Liu, X.,W. Zhao, Buddy: A Virtual Life Coaching System for Children and Adolescents with High Functioning Autism. in *2017 IEEE 15th Intl Conf on Dependable, Autonomic and Secure Computing, 15th Intl Conf on Pervasive Intelligence and Computing, 3rd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress(DASC/PiCom/DataCom/CyberSciTech)*. 2017.
[20] Lund, A.M., Measuring usability with the use questionnaire12, *Usability interface* **8** (2001), 3-6.