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Article

Effects of Virtual Reality on Training in Food Preparation Curriculum for Vocational High School Students with Autism Spectrum Disorder

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Abstract: The improvement of food preparation skills is beneficial for students with autism spectrum disorder (ASD) to strengthen their employment skills and improve their independent living ability. To enhance the skill development of ASD in food preparation with safe approaches, virtual reality (VR) was used in this study. A single-subject research method and multiple probes across the subject's design were used. The participants were three 10th-grade students with ASD in a vocational high school. The training program of a food preparation curriculum was supplemented with sixty-minute VR sessions over 2 weeks, five times per week to collect data on the average procedural accuracy and completion time. The results indicate that procedural accuracy was improved and the effects were retained after the intervention. Although the average completion time was improved, the results of the simplified time-series analysis were not statistically significant.

Keywords: Virtual reality, Vocational high school, Students with autism spectrum disorder, Food preparation curriculum, Effects on the training of food preparation

1. Introduction

The number of people with autism spectrum disorder (ASD) who are employed is highly disproportionate to the number of those in school, with employment rates less than ideal (Hendricks 2010). Furthermore, preparation to enter employment for people with ASD emphasizes training in their chosen vocational skills (Lin and Shy 2018). In the 12-Year Basic Education Curriculum in Special Needs for Disabled Persons, the core supporting courses in vocational high schools are "vocational education". However, these courses are still taught with the traditional learning model of teacher narration and student practice, and limitations in space and time are a barrier to providing individualized learning environments. Students with ASD have significant trouble with social interaction and communication and also have difficulties following social rules (Parsons et al. 2004). Matson and Shoemaker (2009) argued that 25–50% of people with ASD have cognitive impairments and exhibit characteristics of intellectual disabilities (Wilkins and Matson 2009), which is common in attention-deficit hyperactivity and emotional disorders and is accompanied by motor problems such as weird postures, clumsy movements, and walking on tiptoes (APA 2013).

People with ASD may demonstrate superior cognitive abilities in perception and deduction, spatial information processing, and visual-spatial perception. This indicates that people with ASD have advantages in visual learning and represents the main difference with intellectual disabilities (Brentani et al. 2013). People with ASD tend to overfocus on concrete details while ignoring the overall situation and, as a result, they may overlook core points or elements. This, then, contributes to their difficulty in generalizing their skills across scenarios (Carnahan et al. 2009).

The key to teaching with assistive technology is to be user-centric by using instruments, devices, software, and services to assist people with physical and mental disabilities1, maintain or improve their physical function, and promote cross-scenario generalizations (Huang 2014). Goldsmith and LeBlanc (2004) reviewed the positive intervention outcomes of five assistive technologies—tactile and auditory prompting devices, video-based instruction and feedback, computer-aided instruction, virtual

reality (VR), and robotics—in teaching students with ASD. The goal of using assistive technology to teach students with ASD is to improve their communication skills, promote interpersonal interactions, and enhance cognitive functioning. The high level of emulation in VR technologies as well as the fusion and interaction with natural scenarios help students with ASD learn and generalize skills into actual scenarios (Hendricks 2010). VR simulates the real world or an imaginary, fictional world that is immersive, imaginative, and interactive with the use of computers and devices. Users can directly observe, control, and touch the changes to their surroundings or items. VR also includes multisensory human–machine interactions and instant feedback responses. This type of change in mental state, produced by interactions between the individual and the environment, is known as a flow experience. Flow experiences are beneficial to students because they develop skills and take action (Akman and Recep 2019; Feng et al. 2018; Nakamura and Csikszentmihalyi 2014). Intuitive experiential learning methods in VR increase learning motivation and encourage active learning in students. Teachers also instantaneously gain a handle on and log student learning statuses (Gwynette et al. 2018). Therefore, we adopted VR to conduct experiential learning for students with ASD.

1.1 Research Goals

Teachers expect students to generalize their skills in real-life or workplace scenarios. Structured vocational training courses are offered as a common teaching strategy for teaching students with ASD. The training is structured as a timetable-based work system, presented according to the order of the steps of the implementation activities, and displayed as visual sesssion such as simple texts, numbers, symbols, or colors. The work system also provides checklists to help students complete their activities effectively and independently while also recording their learning performance (D'Elia et al. 2014; Mesibov 2018). Based on structured teaching models, VR combines the advantages of video and visualized and individualized adjustments that have been computerized to provide a multisensory teaching environment and experience (Siyam 2019). The 12-Year Basic Education Service Curriculum for Centralized Special Education Classes in Senior High Schools applies to "food preparation skills" as a service skill taught in senior high schools with centralized special education classes (Ministry of Education 2019). In addition to reinforcing skills for independent living and cultivating vocational skills, the training in food preparation skills also emphasizes interacting with family or peers during the food preparation or cooking process as a way of promoting social engagement and developing interpersonal relationships (Goldschmidt and Song 2017; Romero and Francis 2020). Using VR in catering courses can increase practice opportunities by providing unlimited virtual food ingredients for repeated practice while reducing the risk of cuts and injuries (Bozgeyikli et al. 2016; Johnson et al. 2013; Tzeng 2018).

Oberman and Ramachandran (2006) proposed that people understand the behavior or feelings of others through a theory of mind and mirror neurons, by observing and imitating the actions of other people. This neural development is not activated in people with autism. Because people with autism have impaired mirror-neuron systems, their ability to imitate the actions of others and their learning behavior motivations are insufficient. Therefore, people with autism can exhibit characteristics such as clumsy and weird movements, difficulty with fine motor movements, poor balance, impaired motor coordination, and lack of motivation. Zhu et al. (2011) used a brain-computer interface equipped with VR technology to learn and develop interactions with learning materials in a VR environment to improve mirror-neural functions in people with autism and bolster their learning outcomes. Thus, the purpose of this study was to investigate the training effects of VR applications in a food preparation curriculum for students with ASD in vocational high schools.

1.2. Research Questions

Treatment and Education of Autistic and Communication Handicapped Children (TEACCH) proposes a teaching method that organizes and arranges environments to increase structure and reduce complications (Lin and Hu 2014). It establishes a structured physical environment with fixed scenarios and lists the work-systemized time, order, and method of the next task to provide a structured environment. Then, visualized learning features provide visual cues to allow people with autism to understand the relationship between the prompts and the tasks in particular scenarios or fixed steps to guide the student and assist with the organization and integration of environments (Richard et al. 2003). TEACCH offers highly structured approaches for paying attention to children's interests and integrating them into daily activities in natural environments. With this approach, parents can be trained to reinforce independence in the daily lives of children with ASD, which is key to their future employment (Ospina et al. 2008).

Aykut et al. (2014), Ayres and Cihak (2010), Bouck et al. (2014), Chang et al. (2013), Hung and Lin (2012), Johnson et al. (2013) Mechling et al. (2013), Taber-Doughty et al. (2011), and Tzeng (2018) all determined that the process of learning the correct procedure for completing tasks and the number of prompts in the procedure was reduced after intervention skill training for persons with disabilities. The result indicates improved maintenance and generalization in their performance based on the correct rate.

McMorris et al. (2018), Park et al. (2015), Teng et al. (2015), and Xavier et al. (2018) studied the time and performance of people with autism performing tasks. When performing a task for a long time, their cognitive processing and execution abilities drop, leading to inattention, misinterpretation of information, decreased work effectiveness, and prolonged task completion times. VR has been used in exposure therapies for specific phobias and movement rehabilitations. From medical rehabilitations and movement training to games and entertainment, the increasing use of VR helps people with autism learn social and daily living skills effectively (Bozgeyikli et al. 2016; Goldsmith and LeBlanc 2004; Gomes et al. 2018; Parsons et al. 2004).

When teaching practical courses in catering, in addition to lectures and personal demonstrations, teachers use videos and images for students' understanding of curriculum content and assist students with ASD to concretize abstract concepts. Teachers may also use these visual aids to perform a structural analysis of the operational tasks and simplify the complexity that students have in completing their tasks. Lin and Hu (2014) and Huang and Lan (2012), using TEACCH and systematic work analysis, help participants understand the prompts and their connection with implementation tasks, which helps individuals generalize learned skills to actual scenarios. This originates from Vygotsky (1980) who applied scaffolded instruction to disabled students to provide learning directions and trigger their motivations and allow the students to become more focused on the scenario and ultimately complete the task independently (Hsieh 2013). Based on the aforementioned literature analysis, the following research questions were raised in this study.

(1) What are the immediate effects of scaffolded VR on training in food preparation among vocational high school students with ASD?
- Are effects immediate on the rate that the food preparation steps are completed correctly?
- Are effects immediate on the average time that the food preparation steps are completed?

(2) What are the retained effects of scaffolded VR food preparation training among vocational high school students with ASD?
- Are effects on the rate that the food preparation steps are completed correctly retained?
- Are effects on the average time that the food preparation steps are completed retained?

2. Materials and Methods

By featuring a multiple probe design, a type of single-subject experimental design, we recruited three 10th-grade students with ASD in a Taipei City vocational high school with the intentional sampling method. The study was approved by an institutional review board (approval number 201905HM022). The immersive VR food preparation vocational training system which has seven inbuilt food chopping and preparation training modules, developed by Professor J.C. Hong and his team, was adopted as the primary training material. We performed one-on-one training and experiment interventions with the students with ASD. By wearing a VR headset and operating via VR controllers, the participants followed the system instructions to gradually complete the entire vocational training course. This research was reviewed and approved by Research Ethic Committee in National Taiwan Normal University with REC Number 201905HM022.

The formal experiment was conducted in a baseline period, an intervention period, and a retention period. No intervention training was performed during the baseline period. After a stable state was demonstrated in their assessment records, the participants then entered the intervention period. One-on-one individual training was provided for the participants, with each training session lasting 60 min. In consideration of fatigue and dizziness from wearing the devices for a long time, 5-minute breaks were scheduled for every 15 min of training. After each training session, the subjects were evaluated on their food preparation skills. When the subject's assessment record met the predetermined standard at least three consecutive times, the course intervention was withdrawn, and they entered the retention period. The assessment records during the retention period were the same as those during the baseline period in place and method.

The trainers followed the operational process of the immersive VR vocational training system and referenced food preparation assessment charts (Ayres and Cihak 2010; Chang et al. 2013; Johnson et al. 2013) and compiled their work analysis into a food preparation skills assessment chart. We were the primary raters in the study. A vocational evaluator with 18 years of professional experience was also asked to act as a co-rater. We also served as the trainer during the intervention period. The intervention process, the activities, and the system equipment and tools were used following the training activity design. Fixed training times were scheduled for each day. The intervention period was 2 weeks with five sessions each week, resulting in a total of 10 sessions. In each session, one participant was subjected to training, and the other two subjects continued to participate in the original class activities and curriculum. At least 16 food preparation assessments were performed throughout the three experimental phases at the same site for the assessment and training.

The three participants had already completed courses on the use of knives and cutting boards, basic methods of cutting food, and practical food processing. It was confirmed by the teachers that the courses were taught through lectures and physical demonstrations, and immersive VR systems were never used.

2.1 Research Subjects

We recruited the subjects with the following criteria.

(1) Inclusion Criteria

- Students certified with ASD by the Senior High School Special Education Students Diagnosis and Placement Counseling Committee;
- Students without obvious visual or auditory sensory problems or unstable moods and therefore able to participate in the training course normally
- Students who were able to understand simple commands and willing to independently complete command actions under partial oral prompts or by imitating performable actions
- Students with no prior engagement in VR intervention training before the study and up until the training period
- Students who scored 50% or below on the food preparation skills assessment chart in the study
- Signatures of the subject and parents indicating their informed consent to participate in the study

(2) Exclusion Criteria

- Students who had a combination of visual, hearing, motor, and emotional impairments
- Students who could not independently use the VR controllers due to weak cognitive or comprehension abilities
- Students with symptoms of cybersickness, such as nausea, dizziness, or vomiting within 5 minutes of using the VR system
- Students with allergic reactions to touching any of the food ingredients used in the study

The basic demographics of the three subjects are presented in Table 1.

Table 1. Subject Demographics.

Subject	Sex	Age	Disability/Severity	WISC-IV/ABAS-II
A	M	17	ASD/Moderate	FIQ: 42
B	M	16	ASD/Moderate	FIQ: 54
C	F	16	ASD/Moderate	Adaptive Composite: 55

2.2 Research Tools

The research tools were either for training or assessment. Training tools were the immersive VR system, hardware and wearable devices, and the VR food preparation vocational training curriculum. Assessment tools were the food preparation skills assessment chart and the food preparation training log.

The VR simulation system for food preparation had eight training units: kitchen knife use, cucumbers, green beans, Chinese cabbage, tomatoes, onions, carrots, and cabbage. Each unit was divided into practice and assessment modes. In each unit, after a work analysis, the skills to be learned were divided into multiple steps. After their completion, a professional chef and the vocational high school catering teacher reviewed the student's performance based on certification standards to provide expert validity to this study.

The computer used in this study was an Acer NITRO 7, with a 9th generation Intel Core i7 processor. The wearable device was an Acer OJO 500 VR headset, with a weight of 350 g and a resolution of 2880 × 1440, and a screen refresh rate of 90 Hz. User positions were tracked with a built-in gyroscope. The headset was used with an Acer Windows Virtual & Mixed Reality motion controller to control virtual objects with two buttons for selecting and retrieving objects. The system development team originally designed the prototype for general vocational high school students. Thus, the operational instructions were simplified, but not concrete or clear enough for students with ASD. We, therefore, further subdivided each action into more detailed steps. The training curriculum included seven training units. Based on the number of steps and the difficulty, the researcher arranged the units in the following order: cucumbers, green beans, Chinese cabbage, tomatoes, onions, carrots, and cabbage. During the training period of 10 sessions, each session involved three training units: the previous two units for reviewing and a new unit.

2.3 Food Preparation Skills Assessment Chart

The correct completion rate was determined based on the assessment chart. The rater graded the correct completion rate based on the rating standard and the participant's performance. The participant was awarded 3 points for the completion of the action independently, wrong actions that were corrected after a verbal prompt received 2 points, and completing the action only after receiving a verbal prompt was awarded 1 point. Inability to complete the action even after a verbal prompt was scored 0 points. Lastly, the correct completion rate of the unit was calculated according to Eq. (1), then, the correct completion rate of the three units was summed and averaged using Eq. (2) to derive the correct completion rate of the training session.

$$\text{Correct food preparation completion rate} = \frac{Completion\ score}{Total\ possible\ score}\ x\ 100\ (\%) \quad (1)$$

$$\text{Average correct completion rate for 3 units} = \frac{Total\ correct\ completion\ rate\ for\ 3\ units}{3}\ x\ 100\ (\%) \quad (2)$$

Average completion time was the recorded time to complete each operational process according to the steps in the assessment chart. Each step of the process had to be completed and not omitted or skipped. Based on Eq. (3), the food preparation completion time for each unit was calculated. Then, by using Eq. (4), the completion times for all three units were totaled and averaged to obtain the completion time for that session.

$$\text{Food preparation step completion time} = \frac{Total\ time\ (s)\ to\ complete\ the\ steps}{Total\ number\ of\ \ competed\ steps}\ (s) \quad (3)$$

$$\text{Average completion time per step over 3 units} = \frac{Total\ time\ (s)\ to\ complete\ the\ steps\ of\ 3\ units}{3}\ (s) \quad (4)$$

2.4 Food Preparation Training Log

We assigned different symbols according to the assessment rubric. Participants were marked with "+" if they independently completed the action, "V" if they made a wrong move, but completed the action after being given a verbal prompt, "M" if they required a verbal prompt before completing the action, and "–" if they were still unable to complete the action after receiving a verbal prompt.

3. Results and Discussion

3.1. Average Correct Rate of Completing Food Preparation Steps

Due to the coronavirus pandemic, the training and assessment site was relocated from a cooking classroom to an empty classroom. However, the classroom was not equipped with a sink, so the steps "turn on the faucet" and "turn off the faucet" could not be performed. As a result, these two steps were not scored for the calculations. In each stage, the three subjects were assessed on their performance according to the Food Preparation Assessment Chart, covering three units in each session. The effects of the food preparation training for each participant are presented in Fig. 1.

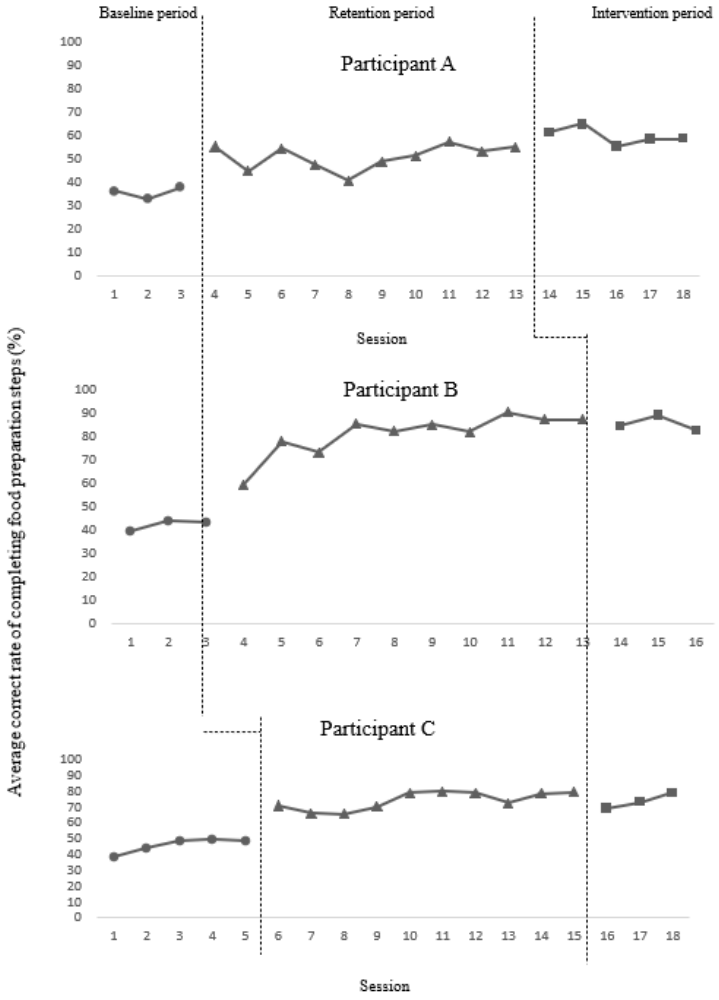

Fig. 1. Average correct rate of completing food preparation steps.

Participant A

(1) Analysis within the stages

The correct rate of completing the food preparation steps was measured a total of three times during the baseline period. The full range of benchmarks was 33.20 to 38.03, and the variation was 1.58. The average benchmark was 35.89, with a stability of 100% and trend stability of 100%. A steady state was achieved, indicating readiness to advance to the intervention stage. During the intervention period, 10 training assessments were performed. The full range of benchmarks was 40.83 to 57.53, and the variation was −0.14. The average benchmark was 51.01 with a stability of 60% and trend stability of 60%. This indicates that the trend in this stage was not a stable rise. One week after the intervention period ended, five assessments were performed. The full range of benchmarks was 55.60 to 65.13, and the variation was −2.93. The average benchmark was 59.92, with a stability of 80% and trend stability of 100%.

(2) Analysis between stages

While transitioning from the baseline period to the intervention period, the benchmark variation was 17.33. No changes were observed in the direction of the trend or the effects, whereas the trend exhibited a transition from stability to instability. The overlap rate was 0%. This indicates that the effects were immediate, and the average benchmark variation was a positive rise, suggesting a trend of improvement post-intervention. While transitioning from the intervention period to the retention period, the benchmark variation was 6.47. Negative changes were observed in the direction of the trend and the effects, and the trend exhibited a transition

from instability to stability. The overlap rate was 20%. The average benchmark rose between these two stages, but the overlap rate was low, indicating poor retention effects.

(3) C statistics

The *Z* values in the baseline period, between the baseline period and intervention period, and between the intervention period and retention period, were −1.11, 2.00, and 1.70, respectively. The C statistic in each stage failed to achieve significance.

In summary, Participant A's performance in the baseline period failed to achieve significance. However, the benchmark stability demonstrated a steady state. No changes were observed in the trend variation between the baseline period and intervention period. The low overlap rate indicated the presence of immediate effects. However, the performance data did not show significance, indicating intervention effects were present. Although the trend variation and effects between the intervention period and retention period exhibited negative trends and a low overlap rate, an upward trend in the average benchmark was observed, which indicated that significance was not achieved, demonstrating retention effects.

Participant B

(1) Analysis within the stages

The correct rate of completing the food preparation steps was measured a total of three times during the baseline period. The full range of benchmarks was 39.60 to 44.17, and the variation was 4.10. The average benchmark was 42.49, with a stability of 100% and trend stability of 100%. A steady state was achieved, indicating readiness to advance to the intervention stage. Entering the intervention period, 10 assessments were performed for training. The full range of benchmarks was 59.57 to 90.47, and the variation was 27.60. The average benchmark was 81.11, with a stability of 70% and trend stability of 80%. This indicates that Participant B demonstrated a steady upward trend in this stage. After a week after the intervention period, five assessments were performed. The full range of benchmarks was 82.87 to 89.43, and the variation was −1.86. The average benchmark was 85.68, with a stability of 100% and trend stability of 100%.

(2) Analysis between stages

While transitioning from the baseline period to the intervention period, the benchmark variation was 15.87. No changes were observed in the direction of the trend and the effects, and the trend transitioned from stable to stable. The overlap rate was 0%. This indicates that the effects were immediately showing a steady improvement post-intervention according to the trend changes. While transitioning from the intervention period to the retention period, the benchmark variation was −2.43. Negative changes were observed in the direction of the trend and the effects, whereas the trend transitioned from stable to stable. The overlap rate was 100%. Although the trend effect between these two stages was negative, the average benchmark exhibited an increase and a high overlap rate, indicating favorable retention effects.

(3) C statistics

The Z values during the baseline period, between the baseline period and intervention period, and between the intervention period and retention period were 0.45, 3.49, and −0.01, respectively. The C statistic showed significance in the baseline period, between the intervention and retention periods, and between the baseline period and intervention period.

In summary, Participant B's performance in the baseline period failed to achieve significance in a steady state. No changes were observed in the trend variation of effects between the baseline period and intervention period. However, the low overlap rate, steady upward trend, and significance indicated the presence of immediate effects. Although the trend variation and effects between the intervention period and retention period exhibited negative trends, the overlap rate was high, and significance was not achieved, which indicated retention effects.

Participant C

(1) Analysis within the stages

The correct rate of completing the food preparation steps was measured a total of five times during the baseline period. The full range of benchmarks was 38.70 to 49.47, and the variation was 9.87. The average benchmark was 45.91 with a stability of 80% and trend stability of 100%. A steady state was achieved, indicating readiness to advance to the intervention stage. Entering the intervention period, 10 training assessments were performed. The full range of benchmarks was from 65.77 to 79.80, and the variation was 8.04. The average benchmark was 74.25, with a stability of 80% and trend stability of 100%. This indicates that a

steady and upward trend existed during this stage. In a week after the intervention period, three assessments were performed. The full range of benchmarks was from 69.33 to 79.30, and the variation was 9.97. The average benchmark was 73.96, with a stability of 100% and trend stability of 100%. Stability was achieved.

(2) Analysis between stages

In transitioning from the baseline period to the intervention period, the benchmark variation was 22.77. No changes were observed in the direction of the trend or the effects, and the trend transitioned from stable to stable. The overlap rate was 0%. This demonstrated that the effects were immediate, and a steady improvement was indicated by the trend changes. In the transition from the intervention to the retention period, the benchmark variation was −10.03. No changes were observed in the direction of the trend or the effects. The overlap rate was 100%. In this stage, the average benchmark exhibited a positive downward change, indicating regression. However, the overlap rate was high, indicating the presence of retention effects.

(3) C statistic

The Z values during the baseline period, between the baseline period and intervention period, and between the intervention period and retention period were 1.95, 3.63, and −0.12, respectively. The C statistic did not show significance in the baseline period or between the intervention and retention period but between the baseline period and intervention period.

In summary, Participant C's performance in the baseline period failed to achieve significance and demonstrated a steady state. No changes were observed in the trend between the baseline period and intervention period. However, the low overlap rate, steady upward trend, and significance indicated the presence of immediate effects. The trend between the intervention period and retention period did not exhibit any changes, whereas the average benchmark displayed positive downward changes. However, the overlap rate was high, and significance was not achieved, which demonstrated the presence of retention effects.

3.2 Average Completion Time for Food Preparation Steps

Because the steps "turn on the faucet" and "turn off the faucet" could not be performed, these two steps were not included in the assessment, and the average complete times were calculated based on the actual number of steps completed. The three participants were assessed on three units during each session in each stage, and the actual completion time for each unit was logged in the food preparation training log (Fig. 2).

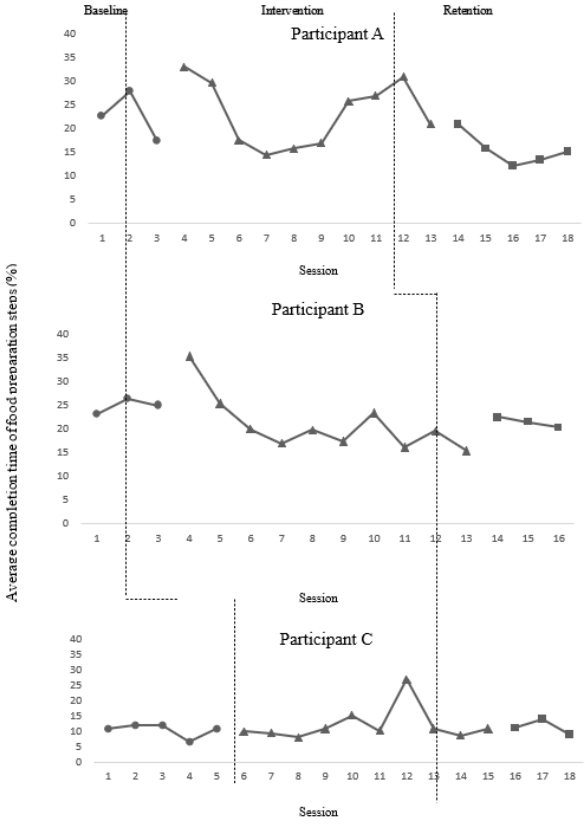

Fig. 2. Average completion time of food preparation steps.

Participant A

(1) Analysis within the stages

Three assessments were conducted during the baseline period. The full range of benchmarks was 17.37 to 28.02, and the variation was -5.39. The average benchmark was 22.72 with a stability of 100% and trend stability of 0%. The trend exhibited a fluctuating negative decline. In the intervention period, 10 assessments were performed. The full range of benchmarks was 14.42 to 33.18, and the variation was -12.20. The average benchmark was 23.23 with a stability of 100% and trend stability of 10%. The changing trend indicates horizontality and showed no improvement or regression. Five assessments were performed a week after the intervention period. The full range of benchmarks was 12.12 to 20.95, and the variation was -5.66. The average benchmark was 15.52 with a stability of 40% and trend stability of 40%. The fluctuating negative decline indicates a trend of improvement.

(2) Analysis between the stages

In transitioning from the baseline to the intervention period, the benchmark variation was 15.81. Negative changes were observed in the direction of the trend and the effects, whereas the trend transitioned from unstable to unstable. The overlap rate was 70%. This demonstrated that the effects were immediate, and the trend displayed a fluctuating negative rise, which indicated that intervention effects were not present. In the transition from the intervention period to the retention period, the benchmark variation was -0.03. Positive changes were observed in the direction of the trend and the effects, and the trend transitioned from being unstable to unstable. The overlap rate was 60%. In this stage, the average benchmark exhibited a negative downward change, indicating improvements. However, the low overlap rate indicated unfavorable retention effects.

(3) C statistics

The Z values during the baseline period, between the baseline period and intervention period, and between the intervention period and retention period were -0.69, 0.85, and 2.33, respectively. The C statistic failed to achieve significance in either the baseline period or between the baseline and intervention periods. A statistical significance of 0.01 was achieved between the intervention period and the retention period.

In summary, Participant A's performance in the baseline period failed to achieve significance and demonstrated a steady state. The changes in the trend variation and effects between the baseline period and intervention period decreased. The overlap rate was high and did not show significance, indicating any immediate effects and no intervention effects. The trend variation and effects between the intervention and retention period were positive, though improvement trends were observed in the average benchmark. However, the overlap rate was not high, and the performance data did not show significance, indicating insignificant retention effects.

Participant B

(1) Analysis within each stage

Three assessments were conducted during the baseline period. The full range of benchmarks was 23.20 to 26.44, and the variation was -1.83. The average benchmark was 24.89, with a stability of 100% and trend stability of 0%. The trend exhibited a stable negative rise. Entering the intervention period, 10 assessments were performed. The full range of benchmarks was 15.41 to 35.47, and the variation was -20.06. The average benchmark was 20.97, with a stability of 40% and trend stability of 40%. The fluctuating and downward trend indicates improvement. One week after the intervention period, three assessments were performed. The full range of benchmarks was 20.41 and 22.55, and the variation was -2.14. The average benchmark was 21.48, with a stability of 100% and trend stability of 100%. The stable downward trend indicates improvement.

(2) Analysis between stages

In transitioning from the baseline period to the intervention period, the benchmark variation was 10.44. Positive changes were observed in the direction of the trend and the effects with the trend transitioning from stable to unstable. The average benchmark declined, indicating an improvement, and the overlap rate was 30%. This demonstrated that the effects were immediate. In the transition from the intervention period to the retention period, the benchmark variation was 7.14. No changes were observed in the direction of the trend or the effects, and the trend transitioned from unstable to stable. The overlap rate was 100%, indicating the presence of retention effects.

(3) C statistic

The Z values during the baseline period, between the baseline period and intervention period, and between the intervention period and retention period were -0.52, 1.79, and -0.29. The C statistic failed to achieve significance in each experimental stage.

In summary, Participant B's performance in the baseline period failed to achieve significance and demonstrated a steady state. The changes in the trend variation and effects between the baseline period and intervention period were positive. Although the overlap rate was low, it did not achieve significance. This indicates that the intervention effects were not obvious. The trend and effects between the intervention and retention period exhibited no changes. However, the overlap rate was high, and the performance data did not achieve significance, indicating the presence of retention effects.

Participant C

(1) Analysis within each stage

Five assessments were conducted during the baseline period. The full range of benchmarks was 6.62 to 12.01, and the variation was 0.20. The average benchmark was 10.44, with a stability of 40% and trend stability of 20%. The trend exhibited a fluctuating negative decline. Upon entering the intervention period, 10 assessments were performed. The full range of benchmarks was 8.09 to 26.81, and the variation was 0.91. The average benchmark was 12.12, with a stability of 40% and trend stability of 30%. The fluctuating negative and upward trend indicates regression. One week after the intervention period, three assessments were performed. The full range of benchmarks was 9.02 to 13.86, and the variation was -2.19. The average benchmark was 11.36 with a stability of 30% and trend stability of 0%. The stable downward trend indicates improvement.

(2) Analysis between stages:

In transitioning from the baseline period to the intervention period, the benchmark variation was -0.94. Negative changes were observed in the direction of the trend and the effects as the trend transitioned from being unstable to unstable. The overlap rate was 100%, and the average benchmark rose, indicating a regressive trend. This demonstrated that no intervention effects were present. In the transition from the intervention to the retention period, the benchmark variation was 0.29. Positive changes were observed in

the direction of the trend and the effects, and the trend transitioned from being unstable to unstable. The overlap rate was 100%, and the average benchmark declined, indicating an improvement and retention effects.

(3) C statistics

The Z values during the baseline period, between the baseline period and intervention period, and between the intervention period and retention period were −0.73, −0.29, and −0.49. The C statistic failed to achieve significance in each experimental stage.

In summary, although Participant C's benchmark and trends did not show significance, their performance in the baseline period failed to achieve significance while exhibiting a steady state, indicating suitability for intervention. The changes in the trend variation and effects between the baseline period and intervention period were negative. The overlap rate was high and failed to achieve significance, indicating the absence of intervention effects. The trend variation and effects between the intervention period and the retention period exhibited positive changes. The overlap rate was high and failed to achieve significance, indicating that retention effects were present.

3.3 Reliability Analysis

We observed and recorded the entire process to provide the video documentation to the co-rater. The assessments were conducted independently. Reliability for Participant A's results in each stage of the experiment was 90–91% with an average reliability of 91%. Reliability for Participant B's results in each stage was 84–100% with an average reliability of 92%. Reliability for Participant C's results in each stage was 83–97% with an average reliability of 90%. The average reliability for the three participants in the same experimental stage was 88–93%, indicating favorable inter-rater consistency reliability.

3.4 Effects and Behavioral Observations of Average Correct Rate of Completing Food Preparation Steps

The participants' learning traits are described according to the training record, then discussed along with their average correct rate and behavioral observations in each experimental stage in this section.

3.4.1 Behavioral Performances and Observations in the Intervention Period

After the intervention training, the average benchmarks of the average correct rate of the three participants, in order, were 51.01, 81.11, and 74.25%, respectively. This result demonstrated immediate effects. The C statistics indicated that Participants B and C exhibited significant intervention effects, whereas Participant A exhibited fewer effects. Participant B displayed the most improvement. The improvements in correct rate were consistent with the studies on food preparation training for disabled students by Ayres and Cihak (2010), Hung and Lin (2012), Johnson et al. (2013), and Taber-Doughty et al. (2010). Therefore, the VR classes triggered increases in Participant B's and Participant C's intrinsic motivation and willingness to engage proactively. This accorded with the results of Bossavit and Parsons (2018) and Koegel et al. (2010).

3.4.2 Behavioral Performances and Observations in the Retention Period

The benchmarks of the participants' correct rate during the retention period were, in order, 59.92, 85.68, and 73.96%, respectively, demonstrating retention effects. The C statistics for Participants B and C showed significance. The three participants gradually memorized the food preparation process, and the number of prompts decreased. They also changed their method of chopping vegetables, which effectively improved maintenance and generalization. This matched the results of Aykut et al. (2014), Ayres and Cihak (2010), Bouck et al. (2014), Chang et al. (2013), Hung and Lin (2012), Johnson et. al (2013), Taber-Doughty et al. (2011), and Tzeng (2018).

3.4.3 Behavioral Performance and Observation in the Baseline Period

The average benchmarks of the completion times of the three participants in this stage were, in order, 22.72, 24.89, and 10.44 s. Participant C had the shortest completion time, followed by Participant A. Participant B had the longest completion time. At the time, Participant C was enrolled in food preparation courses and was able to rely on her learning experiences to complete the food preparation steps without too many pauses throughout the assessment period. Participants A and B had taken courses in food preparation in the previous semester, and their memory of the steps had faded. Therefore, they required more sessions to complete the tasks and, as a result, spent more time completing the tasks.

3.4.5 Behavioral Performances and Observations in the Intervention Period

In the intervention period, the average benchmarks of the participants' completion times were, in order, 23.23, 20.97, and 12.12 s, respectively. Immediate effects were presented only by Participant B. Participant B was able to remember the step process and perform the steps independently, which reduced the time for giving prompts. Participant C insisted on adhering to methods learned in past experiences, and therefore her compliance with the instructions was low, and more sessions were required. As a result, her average completion time was longer than the baseline period. Due to his difficulties in organizing information, inability to focus, and constant questions, Participant A struggled to concentrate on performing the tasks, and we had to constantly remind Participant A to stay on task. In addition, Participant A's fingers were unable to move normally, and therefore, more time was spent wearing the sanitary gloves. These performances were consistent with studies by Teng et al. (2015) and Xavier et al. (2018). In Park et al.'s (2015) study, participants watched both a 3D and a 2D film. As the 3D film had more in-depth information but led to cognitive fatigue and declines in processing execution abilities, participants exhibited an inability to concentrate, misjudgments, and prolonged completion times (McMorris et al., 2018). One inference was that prolonged intervention classes were prone to causing cognitive fatigue, which supports Hong et al.'s (2015) finding that cognitive fatigue is negatively correlated with learning performance.

3.4.6 Behavioral Performances and Observations in the Retention Period

The average benchmarks of the completion times of the three participants in the retention period were, in order, 15.52, 21.48, and 11.36, respectively with retention effects. Using TEACCH and systemized work analysis to enable the participant to understand the prompts and connect them with the execution tasks was conducive to generalizing the learning skills into actual scenarios. This is consistent with studies by Lin and Hu (2014) and Huang and Lan (2012).

3.5 Effects of VR on Vocational Food Preparation Training Curricula

3.5.1 VR Vocational Food Preparation Training Curriculum and the Observation Records

(1) System settings

When chopping the cabbage, prompts were given as dashed lines. Compared with the image prompts in VR scenarios of Chang et al.'s (2013) and Yamaguchi et al.'s (2012), the prompts in this study were more helpful to the user.

(2) Occupational safety and health

Leftover food materials, such as carrot peels and onion skins, were automatically removed by the system when entering the next step. During the actual assessments, the participants were required to discard peels into the food waste bucket before proceeding to the next step, in compliance with the Ministry of Labor's standards for skill certification in food preparation vocations. Hung and Lin (2012) and Madaus et al. (2010) proposed that cultivating health and safety skills in food preparation training also helps students with disability establish correction concepts that facilitate independent living and employment abilities in addition to complying with food safety and health regulations.

(3) Generalization of skills

In this study, the steps were further simplified and subdivided in designing the curriculum and compiling the assessment chart. This was beneficial to the learning of students with ASD, consistent with the work analysis of teaching tasks by Beaudoin et al. (2014), Carnahan et al. (2009), D'Elia et al. (2014), and Mesibov (2018).

3.5.2 Traits of VR Learning among Students with ASD

The virtual kitchen scenario included kitchen equipment, food materials, and two hands. The actual assessment environment was arranged similarly to the VR setup, which assisted with the transference from VR to actual reality and improved user generalization ability. This is consistent with studies by Burke et al. (2018), Parsons and Cobb (2011), and Smith et al. (2014).

(1) Controllable environment

According to Participants A's and C's learning traits, external environmental factors affect their concentration and performance. When conducting training in an immersive VR environment, interference from nonrelevant matters needs to be controlled and isolated. This is consistent with findings by Parsons et al. (2004) and Parsons and Cobb (2011).

(2) Safer learning environment

While performing actual chopping actions, Participants A and C were unable to maintain safe distances between their fingers and the knife. As a result, they were prone to injuries from cutting their fingers. VR involves interactions with virtual objects and, therefore, users can avoid being cut by knives or colliding with objects. Practicing in VR is comparatively much safer than actually operating in a kitchen; this is consistent with Goldsmith and LeBlanc's (2004) study.

(3) Computerized teaching and individualization

Participant C was able to begin following the instructions and complete the tasks, consistent with Southall's (2013) finding that computerized TEACCH is beneficial to the learning of students with ASD. Students can continue to practice according to their learning performance, which conforms with the preference for repetition among people with ASD. This is consistent with studies by Hsieh (2013), Parsons et al. (2004), and Smith et al. (2014).

(4) Tracking interactions

While washing the vegetables in VR, Participant C tended a tendency to use the virtual hands to touch the water column and would focus on the image of the water flowing over the virtual hands. Lotan et al. (2010) argued that VR controllers are more conducive to the VR environment than a computer mouse.

(5) Visual and auditory environment

The participants were observed to be drawn by animation, sounds, and flashing scenes, and they were more focused on completing their tasks and less affected by external sounds and objects. Their performance proved that a VR multisensory learning environment was advantageous to the characteristic of visual learning among students with ASD, consistent with studies by Akman and Recep (2019), Brentani et al. (2013), Feng et al. (2018), and Nakamura and Csikszentmihalyi (2014).

4. Conclusion

For immediate effects on the rate of correctly completing the food preparation steps, the C statistics for participants B and C showed significance and favorable immediate effects. Only Participant B exhibited immediate effects on the visual analysis, but the C statistic did not have significance. Overall, a decreasing trend was present in the average completion times with statistical significance, which indicates a lack of favorable immediate effects. In retained effects on the rate of correctly completing the food preparation steps, favorable retained effects were present among the correct completion rates of all three participants. Among the average completion times of the three participants, only participants B and C exhibited retained effects in their C statistics.

Applied behavior analysis has been recognized as an intervention strategy for autism with therapeutic effects. By understanding the cause and effects of behaviors and their changes through control, teachers more actively discover behavioral problems and systematically review teaching outcomes (Feng et al. 2015). However, applied behavior analysis must be performed by psychologists, teachers, or trained professionals. Such analysis is not beneficial to students with ASD in fields lacking professional talent (Beaudoin et al. 2014). The limitations of this study lie in that these results could not overly generalize the findings beyond a case study. Therefore, future studies can adopt single-subject methods such as multiple or alternating intervention designs. A controlled experiment design with two groups is necessary to investigate whether immersive VR training is superior to other teaching intervention methods. We also suggest prolonging the experimental period or increasing the number of intervention sessions as well as conducting the assessments in actual cooking classrooms to improve the rigor of the study and to investigate more empirical findings. Furthermore, future studies can assess generalization with different food materials, equipment, preparation processes, or natural scenarios to expand the application range of food preparation skills. Finally, future studies can also develop immersive VR training systems for more activities, such as baking, automobile washing, retail service, or leisure activities.

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