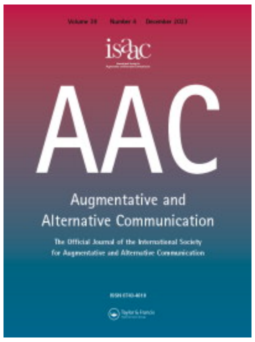

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RESEARCH ARTICLE

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Feasibility of an eye-gaze technology intervention for students with severe motor and communication difficulties in Taiwan

Yu-Hsin Hsieh[a], Mats Granlund[b], Ai-Wen Hwang[c,d†] and Helena Hemmingsson[a]

[a]Department of Special Education, Stockholm University, Stockholm, Sweden; [b]CHILD, School of Health and Welfare, Jönköping University, Jönköping, Sweden; [c]Graduate Institute of Early Intervention, College of Medicine, Chang-Gung University, Tao-Yuan City, Taiwan; [d]Department of Physical Medicine and Rehabilitation, Chang Gung Memorial Hospital, Linkou, Kwei-Shan, Tao-Yuan City, Taiwan

ABSTRACT

Eye-gaze technology provides access to a computer through the control of eye movements, thus allowing students with severe motor and communication difficulties to communicate and participate in curriculum activities and leisure; however, few studies have investigated whether any challenges exist to its implementation. This study examines the feasibility for teachers, parents, and therapists of applying an eye-gaze technology intervention for students with severe motor and communication difficulties in everyday settings. A mixed-method design was applied, focusing on the acceptability, demands, implementation, and practicality of the technology applications. Data was collected from 16 participants who assisted five students using eye-gaze technology in a previous 6-month intervention. The intervention comprised (a) use of eye-gaze devices with individualized content; and (b) services including training in use, team meetings, and bi-monthly support on implementation problems. The results showed that the participants perceived the technology as appropriate to enhance interaction and understanding of the students' learning and communication messages. Portable and easy-to-adjust systems were crucial to apply eye-gaze technology in different contexts. Improving eye-gaze services was required to afford in-service education, follow-up services, and loaning programs for sustainable implementation. The facilitators and barriers could guide researchers and practitioners to enhance the implementation of eye-gaze technology.

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Acceptability; gaze-controlled computer; implementation; participation; students with severe disabilities

With the advances in information communication technology, computers have become valuable educational tools to promote students' motivation and engagement in educational activities and digital communication (Chen & Tsai, 2021; Lidström & Hemmingsson, 2014). For students with severe motor and communication difficulties, using computers as assistive technology (AT) with tailored access methods is essential to promote their participation. Such use can help them to communicate with others and can support their participation in learning tasks as well as play and leisure activities (Brodin, 2010; Lidström & Hemmingsson, 2014); however, to incorporate AT into everyday life, it is crucial that those in the students' proximal environment perceive the use of this technology as feasible and valuable. This recognition justifies their investment of time and energy in supporting students to utilize AT and thus bolsters the sustainability of intervention effects.

The provision of inclusive education has shifted from a deficit-based model of disability (focused on students' impairments) to biopsychosocial perspectives as expressed in the International Classification of Functioning, Disability and Health framework (WHO, 2007). The multiple perspectives highlight that a student's communication and participation in play and learning is related both to environmental facilitators and barriers and to their body functions. Environmental support such as the provision of AT is therefore essential for students with severe disabilities to develop and use opportunities for participation in school and the community (Borgestig et al., 2017; Rogers & Johnson, 2018). Evidence-based practices have suggested embedding AT into individualized education programs (IEPs) to enhance curricular accessibility and students' communication and learning (Alquraini & Dianne Gut, 2012; Rogers & Johnson, 2018). Such strategies require that educational providers and communication partners adapt both their behavior and the physical environment to the student, for example by facilitating use of eye-gaze technology.

Students with severe motor and communication difficulties, including common diagnoses such as severe cerebral palsy, have limited motor functions required to operate a computer (Novak et al., 2012). In addition, there is a high probability of coexisting cognitive or visual problems for these children (Novak et al., 2012). Due to restricted natural

CONTACT Yu-Hsin Hsieh yu-hsin.hsieh@mcgill.ca McGill University, School of Physical and Occupational Therapy, 3630 Promenade Sir-William-Osler, Montreal, Quebec H3G 1Y5, Canada.

†This article is based on the dissertation completed by Yu-Hsin Hsieh (2022). Yu-Hsin Hsieh was a Ph.D. candidate in the Department of Special Education, Stockholm University at the time the study was conducted and is now a postdoctoral researcher in School of Physical and Occupational Therapy, McGill University.

This article has been corrected with minor changes. These changes do not impact the academic content of the article.

speech, they usually communicate nonverbally through gestures, vocalization or eye-pointing (Dhondt et al., 2020).

Eye-gaze technology is a type of AT that enables students with severe motor impairments to access and control a computer using their eyes instead of using a traditional keyboard and mouse, or alternative solutions such as switches controlled by head movements (Majaranta & Donegan, 2012). Eye-gaze technology works by emitting an infrared light that is reflected off of the student's eyes. The eye-gaze camera captures the reflected light and its special software filters and analyzes the student's gaze direction. As such, it allows the student to point with their eyes by directly looking at the target on the screen and to make on-screen selections (e.g., activate symbols) by maintaining their gaze on the desired target for a set amount of time (known as the dwell time) (Majaranta & Donegan, 2012). Compared to indirect selection methods (e.g., scanning using switches), it is less physically demanding and more efficient (Majaranta & Donegan, 2012); thus it may be a preferred choice for students with severe physical disabilities to access a computer for educational and leisure activities and as a method of aided augmentative and alternative communication (AAC) (Borgestig et al., 2021; Perfect et al., 2020). Eye-gaze technology can be an added-on system, in which an eye-gaze device is externally connected to a computer, or a built-in system where the device is integrated into a computer screen (Lui et al., 2022; Majaranta & Donegan, 2012).

A growing number of intervention studies have shown that children with severe motor and communication difficulties can learn to use eye-gaze technology and benefit from using the technology to participate in computer activities (Borgestig et al., 2017, 2021; Hsieh et al., 2022). Some studies indicate that improving communication partners' knowledge and skills and children's interest in its use are important facilitators for the technology uptake, whereas lack of professional services to support use, lack of access to suitable eye-gaze systems, technical problems, or children's health issues could hinder the implementation (Holmqvist et al., 2018; Karlsson et al., 2021; Perfect et al., 2020). It is important to examine the extent to which communication partners such as parents, teachers, and therapists as well as the users perceive eye-gaze technology as feasible within everyday practices, focusing on both the facilitators and barriers of using the technology.

Feasibility studies address how far an intervention can be conducted as planned before proceeding to a large-scale study and whether problems might compromise the acceptability and delivery of the intervention in real-life settings (Bowen et al., 2009; Orsmond & Cohn, 2015). This study focuses on the feasibility of implementing an eye-gaze technology intervention in Taiwan, where the application of the technology for children is in the initial phase. In Taiwan, qualified physiotherapists (PTs), occupational therapists (OTs), and speech-language pathologists (SLPs) with AT certificates at AT centers or medical hospitals prescribe and assess eye-gaze devices. Individual training is typically provided by therapists working in healthcare rehabilitation services or school systems. The government offers subsidies for eye-gaze devices, but parents may need to pay additional expenses. Previous studies have reported that insufficient follow-up services and high-tech in-service training may lead to AAC devices not being used as expected (Tsai, 2019). There is limited evidence on what practical components to consider when delivering the intervention and the extent to which the intervention is perceived as acceptable by users and communication partners. Therefore, this study plans to add evidence by (a) identifying important factors and resources required for implementing the technology within everyday practices, and (b) investigating what aspects of an intervention communication partners perceive as acceptable or challenging for students using the technology.

The aim of this study was to investigate the feasibility for teachers, parents, and therapists as communication partners of applying eye-gaze technology in educational settings or at home for students with severe motor and communication difficulties in Taiwan. The following research question was asked: What feasibility aspects concerning implementing an eye-gaze technology intervention aimed at participation in computer activities for play, communication, and learning are deemed as important by the communication partners?

Method

This study is part of an eye-gaze technology intervention project in Taiwan conducted between September 2019 and July 2020. The previous intervention study (Hsieh et al., 2022) examined the effects of a 6-month eye-gaze technology intervention on children's participation in computer activities and technology usability. The current study was an extension of the earlier work to investigate the feasibility of this intervention in a Taiwanese context.

During the previous eye-gaze technology intervention (Hsieh et al., 2022), the students accessed an add-on eye-gaze device, the Tobii PCEye Mini[1], borrowed from the Tobii company. Each student received ready-made leisure programs (e.g., HelpKidzLearn[2]) and customized content, including communication, learning, and leisure pages adapted to their individual needs and interests (e.g., Communicator 5[3]). The research team provided a 2-day workshop for therapists and individual training for the parents/teachers on the use of the eye-gaze systems and communication support strategies. Service delivery included one planning meeting in which the parents, teachers, therapists, and the researcher jointly set goals and planned activities, one follow-up meeting to evaluate the student's progress and modify strategies, and individual support twice a month for parents and teachers from the therapists and the researcher on pedagogical, gaze-control and technical problems. This feasibility study further examined whether these intervention components worked in everyday life based on the framework for feasibility studies proposed by Bowen et al. (2009).

Participants

The participants of this study were recruited from a convenience sample. The inclusion criteria were participants who

Table 1. Demographic data for five students (all names are pseudonyms).

Student	Communication partners	Sex	GMFCS, MACS, CFCS	Communication methods	Cognition	Epilepsy	Vision	Hearing
LiHao	Mother, PT	M	V, V, IV	Facial expression, vocalization, gaze fixation on objects; can express clear yes/no	Unspecified impairment	Yes	Myopia, astigmatism, strabismus	Mild impairment
ChiaYu	Teacher, mother, PT[a]	F	V, V, V	Facial expression, gaze fixation on objects; showed unclear yes/no	Unspecified impairment	Yes	None	None
ShuWen	Mother, SLP, PT[a]	F	V, V, IV	Facial expression, shifting gaze between people and objects, body movements; can express clear yes/no	Unspecified impairment	No	None	None
YiFen	Teacher, mother, OT, SLP	F	V, IV, IV	Facial expression, vocalization, inconsistent gaze fixation on objects; showed unclear yes/no	Unspecified impairment	No	Strabismus, hyperopia	None
HanHan	Teacher, chief of educare, parents, OT	M	V, V, IV	Facial expression, vocalization, gaze fixation on objects; can express clear yes/no	Unspecified impairment	No	Strabismus, myopia, astigmatism	None

Note. GMFCS = Gross Motor Function Classification System. MACS = Manual Ability Classification System. CFCS = Communication Function Classification System. PT = physiotherapist. SLP = speech language pathologist. OT = occupational therapist.
[a]"Two participants had the same physiotherapist".

had experiences of a child/student (a) involved in the previous eye-gaze technology intervention and who used the technology in everyday contexts between October 2019 and July 2020, (b) aged 1 to 25 years, and (c) experiencing severe motor and speech impairments.

A total of 16 participants who assisted five students using eye-gaze technology during the previous intervention were invited to participate in the current study. All agreed and signed the written consent forms. They were notified that they could withdraw at any time without explanation. The participants included (a) parents of five children/youths; (b) four teachers; and (c) six therapists who worked in an educational setting or a rehabilitation hospital (two PTs, two OTs, and two SLPs) (Table 1).

The parents were between 38 and 54 years old; five had a college-equivalent degree. The teachers were 26 to 48 years old, were all females, and had worked for 3 to 20 years with students with severe disabilities in educational settings. One teacher did not have previous experience with eye-gaze technology, and the other three had some experience ranging from 2 to 20 months of using the technology before the intervention. The therapists were 25 to 59 years old, were all females, had worked in pediatric rehabilitation for 2 to 25 years and had received training on AT applications. Two of them had no prior eye-gaze technology experience and the other four had 4 to 18 months of experience providing the technology services.

The students (LiHao, ChiaYu, ShuWen, YiFen and HanHan [pseudonyms]) were between 3 and 22 years old and had severe cerebral palsy or neurometabolic disorder. They attended special classes in preschool/school or a child development centers/adult daycare centers and lived with their parents. All had severe gross and fine motor function restrictions, used transported wheelchairs, and had limited functional use of switches or other access methods for a computer. All students had an intellectual disability and three had visual impairments. They communicated on a pre-symbolic level and mostly used unaided AAC such as vocalizations, facial expressions, or looking to interact with familiar people. All had limited experience using eye-pointing communication and low-tech AAC. Table 1 presents their characteristics.

Setting

The study took place in the student's home and/or educational settings (i.e., a school, a child development center or an adult daycare center where educational activities are provided).

Research design

The current study utilized mixed methods as Bowen et al. (2009) and Orsmond and Cohn (2015) recommended for feasibility studies, and employed a convergent design approach (Creswell & Creswell, 2018). The qualitative and quantitative data were collected and analyzed in parallel (Creswell & Creswell, 2018; Teddlie & Tashakkori, 2009) and were finally integrated under four focus areas: Acceptability, Demand, Implementation, and Practicality (Bowen et al., 2009). *Acceptability* examines if and why the parents, teachers and therapists perceive the eye-gaze technology intervention as suitable and satisfactory. *Demand* examines the actual use of the technology in an everyday context. *Implementation* investigates the factors influencing the ease or difficulty of the intervention implementation and the required resources. *Practicality* examines the extent to which the eye-gaze technology intervention can be delivered at home or in educational environments. This approach allowed investigation of multiple perspectives and provided a better understanding of the feasibility of the technology intervention. Table 2 gives a summarized description of key areas of focus and their definitions, sub-areas, data collection methods, and methods for data analyses.

The eye-gaze technology project was approved by the ethical review boards in Taiwan (201812EM004) and in Sweden (Dnr 2019-04902). To protect confidentiality, personally identifiable data was not individually reported.

Researchers

The authors have diverse expertise and experience in special education, psychology, and pediatric rehabilitation. The first author, who has a background in physical therapy and special education, conducted and coded all interviews. Her prior clinical experience, working with students with motor and communication difficulties and collaborating with interdisciplinary teams in AT provision in Taiwan, facilitated her understanding of the cultural and clinical barriers and facilitators experienced by the students and other stakeholders. This experience helped prompt follow-up questions and encouraged participants to delve deeper and clarify their opinions during the interviews. All other authors, as senior researchers in Sweden and Taiwan, supported the first author throughout the study. Their extensive experience in the AAC field, in participation-based research, or in eye-gaze technology research contributed insights useful for interpreting the data concerning the areas of the feasibility framework. The team's varied cultural and academic backgrounds, along with their research experiences, collectively shaped the interpretations and analyses of this study.

Materials and measures

The qualitative data sources of the current study included semi-structured interviews about participants' perspectives and experiences and therapists' documentation on their discussions with parents/teachers. Quantitative data comprised parents'/teachers' satisfaction with the AT, using the Taiwanese Version of Quebec User Evaluation of Satisfaction with Assistive Technology (T-QUEST), and the student's computer use from a computer use diary.

Interview guide

An interview guide with questions related to the areas of Acceptability, Demand, Implementation, and Practicality was developed and modified to match each group of participants (i.e., teachers, parents, therapists). The interview had five open-ended questions as follows: How has your child/student been using eye-gaze technology? (Demand and Acceptability areas) What were the changes since starting to use eye-gaze technology during this period? (Acceptability) How was your experience of supporting the child/student in using eye-gaze technology? (Implementation) What are your thoughts about the services for eye-gaze technology? (Acceptability and Implementation) What are your thoughts about supporting your child/student in using eye-gaze technology in the future? (Acceptability, Implementation, and Practicality). The researcher used follow-up questions and probing (Kvale & Brinkmann, 2015) when needed to get a deeper understanding related to the topics, such as "What activity did your child/student like to do or dislike doing via eye-gaze technology?" (Acceptability) "Did you find any difficulties in supporting your child/student in using eye-gaze technology in everyday life? What were these?" (Implementation). The researcher encouraged the participants to describe both positive and negative aspects of their experiences to get comprehensive perspectives on the feasibility of the eye-gaze technology intervention.

Therapist consultation form

A structured consultation form related to the Implementation section was developed, and had two open-ended questions: (a) What problems or difficulties has the student or teacher/parent encountered using the gaze-controlled computer in the past weeks? (b) What solution or suggestion was provided to the teacher/parent? The therapists filled in the form documenting difficulties the teachers/parents had faced in implementing the intervention and the solutions pertaining to the problems they discussed during individual support for each student.

T-QUEST

The T-QUEST (Mao et al., 2010) was used to evaluate parents' and teachers' satisfaction with assistive devices and services (Acceptability area). The instrument includes eight items in the Device subscale and four items in the Service subscale. Each item is rated using a five-point scale from 1 (*not satisfied at all*) to 5 (*very satisfied*). The psychometrics of T-QUEST showed good test-retest reliability (ICC = 0.90-0.97), internal consistency (Cronbach's alpha = 0.84-0.90) and appropriate validity (Mao et al., 2010).

Table 2. Description of four areas of focus for feasibility, sub-areas, data collection methods, and methods for data analyses.

Area of focus for feasibility/definition	Sub-areas	Data collection methods	Methods for data analyses
Acceptability: To what extent is the eye-gaze intervention judged as suitable, satisfying or attractive to participants	Perceived appropriateness	Semi-structured interviews	Deductive content analysis
	Intent to continue use	Semi-structured interviews with parents and teachers	Deductive content analysis
	Satisfaction with devices and services	T-QUEST	Descriptive statistics
Demand: To what extent is the AT likely to be used	Actual use of eye-gaze technology	Computer use diary	Descriptive statistics
Implementation: To what extent can the eye-gaze intervention be successfully delivered to intended students in everyday contexts	Factors affecting implementation ease or difficulty	Semi-structured interviews, Therapist consultation forms	Deductive content analysis
	Amount, type of resources needed to implement	Semi-structured interviews	Deductive content analysis
Practicality: To what extent can the eye-gaze intervention be carried out using existing means, resources, and circumstances	Ease of carrying out in everyday contexts[a]	Semi-structured interviews	Inductive content analysis
	Ability of students to carry out intervention activities	Semi-structured interviews	Deductive content analysis

Note. T-QUEST = The Taiwanese Version of Quebec User Evaluation of Satisfaction with Assistive Technology.
[a]New subcategory from inductive content analysis

Computer use diary

A computer use diary developed and tested in a previous study (Borgestig et al., 2017) was used (Demand area). Parents/teachers documented computer use at home/in school based on their daily observations. The content included (a) diversity (types) of computer activities the child performed each day, (b) duration of computer use for each activity, and (c) the number of times the computer was used and when it was used. The diary data showed acceptable interassessor reliability (percent agreements = 77.8%-100%) with log data in the study by Hsieh et al. (2022).

Procedures

Data collection

Data collection involved three stages, as displayed in Figure 1. (a) At baseline, the researcher collected students' profiles and demographic data from medical charts and the reports from participants; (b) During the 6-month intervention, the parents and teachers documented the child's computer use every day in the computer use diary. The therapists documented the implementation problems and solutions every month with the help of the structured consultation form; (c) Immediately after the end of the intervention, an independent assessor collected the satisfaction questionnaire (T-QUEST) from the parents and teachers. In addition, individual interviews with participants were conducted by the researcher (first author). In total, the participants participated in 16 individual interviews. Each interview was recorded using a digital audio recorder. The mean duration for each interview was 59 min (range = 42-85 min), and the total duration of all interviews was 15 hr 50 min.

Data Analysis

A deductive approach to content analysis was used to analyze qualitative data (Hsieh & Shannon, 2005; Kyngäs & Kaakinen, 2020). Interviews were transcribed verbatim. The process of data coding was conducted using Nvivo 12 software (QSR International, 2022). The first author analyzed the interview and descriptive data following the procedure recommended by Hsieh and Shannon (2005). First, the author read each transcript several times and highlighted all text that on first impression appeared to represent an area of focus for feasibility. Second, all highlighted passages were coded and assigned to categories using the predetermined areas. Then, the text related to the area of each feasibility category was highlighted and subsequently sorted into subcategories. There was an iterative process that involved the transcription data, the categories and the subcategories of the feasibility aspects. Third, if the text could not be categorized with the initial codes, an inductive approach was used as a supplement and a new code was given (Kyngäs & Kaakinen, 2020). Descriptive statistics were used to summarize the results for computer use from the computer use diary. Mean scores of T-QUEST were calculated for each subscale and total scale.

The quantitative and qualitative data were analyzed concurrently and integrated when presenting and discussing the findings according to the framework of the four areas of feasibility by Bowen et al. (2009). The data from the therapist consultation form was compared and merged with the interview data in the implementation area. Findings from T-QUEST were integrated into the acceptability aspect and linked to interview data in the interpretation phase to provide a complementary understanding of the feasibility of the intervention.

Reliability

To enhance trustworthiness in the current study, peer validation (Kvale & Brinkmann, 2015) was used. Data analyses, categories, and subcategories were discussed by the coauthors, who had extensive experience in qualitative methods. In addition, data triangulation (Kvale & Brinkmann, 2015) was applied to compare the interview data from the teachers, parents and therapists who supported the same students in order to identify similarities and differences in their viewpoints and experiences. To increase credibility, all participants were provided with transcripts of their interviews for member validation (Kvale & Brinkmann, 2015). A total of 14 participants replied and verified the accuracy of the transcripts.

Results

The results are structured according to the four areas of description proposed by Bowen et al. (2009): Acceptability, Demand, Implementation, and Practicality. Table 3 presents the summarized findings of the facilitators and barriers in the four areas of focus.

Acceptability

Perceived appropriateness

Most participants described the eye-gaze technology services, which included two meetings and individual support bi-monthly, as acceptable for setting up reasonable goals, developing or modifying strategies to support the students' use, and solving implementation problems. Participants perceived the eye-gaze devices as sensitive in detecting the student's eyes. The gaming program and customized content fitted the student's experiences and interests and kept them engaged; however, some parents said that it was time-consuming to attend meetings and bi-monthly discussions as they needed to rearrange their work. Participants also recognized that a long learning journey was required for the students to learn and use the technology functionally in daily life.

Teachers described the intervention as suitable for better understanding the students' learning motivation and performance and for providing feedback on students' responses because the technology allows the communication partner to observe where the student is looking on a screen. Selections made by the students' sustained gaze were spoken aloud by the computer, enhancing the interaction between the partner and the student. As one teacher

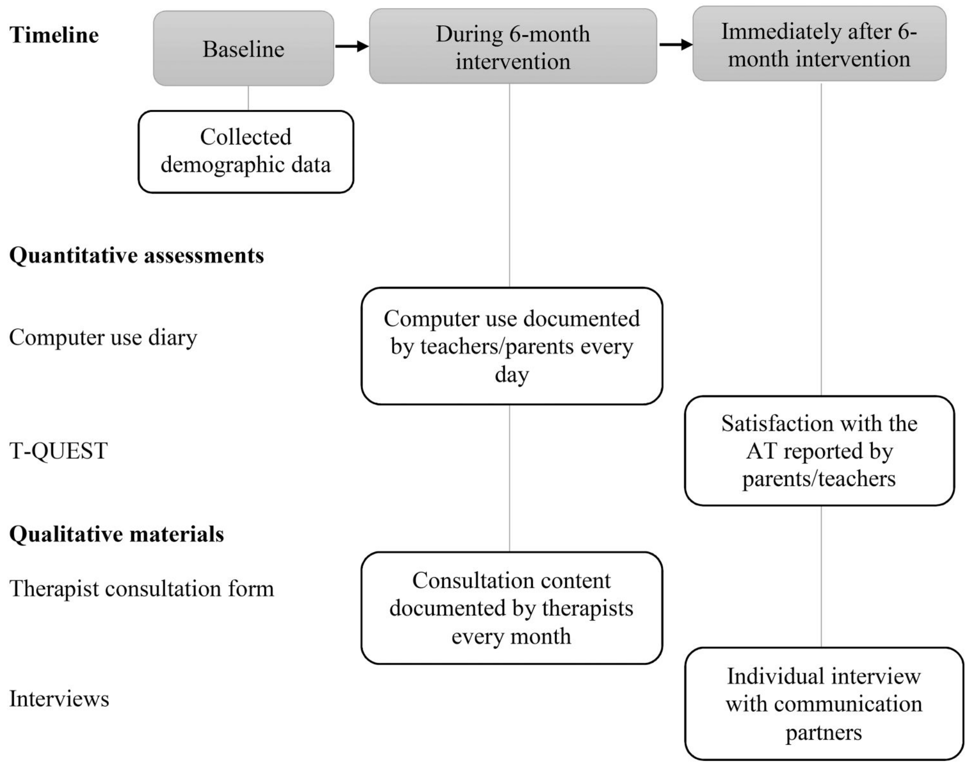

Figure 1. Flowchart of data collection.
Note. T-QUEST = The Taiwanese Version of Quebec User Evaluation of Satisfaction with Assistive Technology.

explained: "Through this technology you can get to know this little girl better and her learning patterns, and how long she can be attentive" (Teacher 3). Additionally, teachers emphasized that students appeared more engaged when using a computer than when responding to low-tech pictures.

The participants mentioned both the appropriateness and inappropriateness of using eye-gaze technology as a communication method. On the one hand, the intervention enhanced dyadic communication as it provided an interface for others to understand the student's communication messages better. Moreover, the triadic communication structure (student, computer, communication partner) reminded the participants to give space for students' self-expression rather than speaking for them. Some parents also noted that children's eye-pointing communication became clearer even without the technology, indicating that the use of the technology also helped to develop eye-pointing ability. As one parent said, "The duration of her gaze has improved, and the message she communicates is much clearer. Previously, her eyes were fluttering, and it was hard to tell where she was looking" (Parent 3). On the other hand, some participants reported that it was less appropriate when the students needed to communicate their needs in a timely manner (i.e., when they needed to go to the toilet). As for using the eye-gaze systems, the students needed to sit in a stable position and the device with a table stand had restricted mobility. Some therapists proposed a combination of eye-gaze technology with low-tech communication methods. "We can't use this all the time. It is important to generalize into other activities (i.e., a combination with low-tech E-trans). (…) because they complement each other, and the effect can be cumulative" (SLP 2).

Participants described the intervention as appropriate for increasing the students' autonomy and initiative because the students could actively perform activities and choose what to do rather than relying totally on assistance from others. This was exemplified by several participants. Some valued that the students used the technology to play games/watch videos like peers or siblings, thereby gaining enjoyment and a sense of accomplishment. Some participants said that the students' use of the technology to interact with others increased social closeness. As one teacher mentioned: "Before, he had few interactions with peers. (…) We started putting eye-gaze activities into the classroom and found his peers liked it. He showed a sense of achievement when choosing the music to interact with his classmates" (Teacher 2).

Intent to continue use

Teachers and parents recognized the importance of continuously using eye-gaze technology after the intervention as they noted that the students showed growing adaptation and acceptance with the use of the technology. Still, they expressed different opinions regarding the contexts for future use. Some teachers intended to increase the frequency of use in the classroom activities by adding the technology to the IEP. Some parents favored using the technology for leisure at home and for learning in schools. As one parent said, "I would prefer using the technology at both the center and at home since feedback from peers and teachers motivates him more and enhances his performance,

Table 3. Summary of facilitators and barriers for four areas of focus: acceptability, demand, implementation, and practicality.

Areas of focus/sub-areas	Facilitators	Barriers
Acceptability		
Perceived appropriateness	Appropriateness for developing joint goals, modifying strategies, and solving problems	Time consuming for meeting and discussions
	Teachers better understood the student's learning patterns	A long learning journey
	Enhanced communicative interactions	Communicating needs in a timely manner
	Increased student autonomy and initiative	
Intent to continue use	Teachers/parents expressed the intention and importance for the students to use the technology continuously	Different concerns about the contexts for future use
Satisfaction with devices and services	Satisfaction with the eye-gaze devices and services in general	The item of easy-to-adjust with the lowest satisfaction score
	The easiest-to-use item with the highest satisfaction score	
Demand		
Actual use of eye-gaze technology	Increased diversity of activities in play/leisure, communication and learning areas[a]	Mean frequency of computer use 2.2-3.6 days/ week, not everyday
	Increased duration of computer use	
Implementation		
Social context	Teachers' competencies to support students' needs	Staffing shortages
	Partnering in proximal environments	Time constraints due to care burdens and other routines
Eye-gaze devices	Functional hardware	Inconvenience: device mobility, ergonomic adjustments
	Motivating content	Not easily adjusted pages
Student factors	Appropriate head and trunk positioning	Not adapted to positioning chairs
		Fluctuating health conditions
Amount/type of resources needed	Team collaboration	Follow-up services to expand communication opportunities
	Device availability	No loaning program
		Lacking in-service education
Practicality		
Ease of carrying out in everyday contexts	Embedding into routine activities and educational plan	Separate training from group activities
	Team working in the same unit	Team reduced shared observations
Ability of students to carry out activities	Motivation to learn	Few eye-pointing communication and choice-making experiences
		Not full understanding of the AT as a communication mean
		Eye control difficulties

[a]Play/leisure activities included games, music, and watching videos and photos. Examples of communication included making choices (e.g., activities, songs, people), giving comments, and engaging in simple communication in everyday contexts. Learning activities were, for example, preschool activities (e.g., colors, picture books), language or math lessons, and presentation of weekend activities.

compared to using it solely at home" (Parent 1). Some parents preferred to use it in schools because the children's stamina decreased after class.

Satisfaction with devices and services

The assessment from T-QUEST indicated that parents and teachers in general were satisfied with eye-gaze devices, with the subscale mean score range being 3.38-5.0 (5 being the most positive rating). Additionally, they showed satisfaction with the eye-gaze service during the intervention, with the score ranging from 3.5 to 5.0. The item with the highest satisfaction score was *easy to use* ($M = 4.57$), the lowest score was easy to adjust ($M = 4.0$). The two most important items for parents and teachers were effectiveness (5/7) and professional services (4/7).

Demand

Actual use of eye-gaze technology

During the intervention period, the students' use of computer activities ranged from three to six activities in three areas: play/leisure, communication/choice-making, and learning. All used eye-gaze technology for play/leisure and communication/choice-making. The mean frequency of computer use was 2.2-3.6 days per week. The mean duration of computer use increased from 12.4 to 24.6 min per user day in the first 3 months of the intervention to 21.3 to 36.6 min per user day in the second half of the intervention.

Implementation

Factors affecting implementation ease or difficulty

The facilitators or barriers that might have influenced the ease or difficulty of implementation are structured into the social context in which students used the technology, eye-gaze devices, and student factors, as displayed in Table 3.

Teachers' Competencies to Support Students' Needs was identified as a facilitator in social context. The teachers adjusted the order and the level of difficulty in computer activities, and the environment arrangement according to students' health situation, attention and interests, which enhanced the smoothness of operation and increased the student's engagement in activities. "The teacher actually started from what the student was interested in, making it easier for her to succeed, and then tried something more difficult, or something new" (SLP 2).

Partnering in proximal environments. Parent-teacher collaboration on implementation was reported to facilitate opportunities for students to use the computer in different contexts and to enhance their performance. "We started to involve the family in providing computer use at home. He [the student] seemed motivated, and his family was cooperative. After the winter vacation, we found his performance in operating a computer had become better than before" (Teacher 1). Partnering with other classroom teachers was found to enhance support for the students' computer use, whereas staffing shortages resulted in implementation difficulties. Time constraints because of care loads and other family routines were a challenge for some parents as regards setting up the system and supporting children's use frequently.

Functional hardware. The devices were reported to be easy to operate, and functioned well in general. Still, sometimes there were technical problems in that the device was not responsive to the students' choices, which could influence their motivation.

Motivating content. Most participants found that the gaming software was easy to implement and the game tasks with different levels and feedback motivated the students to learn the new technology and enhanced their development of the eye control skills needed to operate a computer. Customized pages with speech output function were identified as convenient. However, some participants said that designing and modifying pages and inter-page links based on the context was not easy enough. They indicated a need for more training and continuous support in adjusting content; as one therapist said, "Parents will need ongoing consultation regarding the design of communication layouts, including the order and placement of communication pages, taking into account the frequency of use in communication" (SLP1).

Convenience. The constrained mobility of the eye-gaze systems when mounted on a laptop and table was a shared impediment, resulting in difficulties in implementing the AT in various classroom locations and across settings. As one teacher mentioned, "It would be wonderful if the eye-gaze system could follow the student and his wheelchair, as we could apply it in more situations" (Teacher 2). Concerning the limited space in the environment and device safety, the laptop might not be mounted on the table all day long. Thus, the accessibility of the computer was affected. Moreover, teachers said that sometimes it took effort to adjust the computer's ergonomic position to suit the student's seating position. If the screen was in an inappropriate position it could influence the smoothness and accuracy of gaze selections.

Positioning. An appropriate seating positioning was identified as essential for the students in order for them to save energy and enhance their operation of a computer. Some therapists reported that head positioning needed to be checked carefully as it facilitated the students' eye exploration and gaze selection. Some young students had not yet developed the ability to sit for long periods in a positioning chair regularly at home, and extra time and effort was required for the adults to position them, thus influencing the frequency of use.

Health. Participants said that the fluctuating health conditions (e.g., sickness, seizures) and weather changes could substantially impact the students' body functions, attention, or endurance when using a computer. The students might easily get tired or become less attentive, in which case it took much effort for teachers or parents to encourage the student's involvement.

Amount and type of resources needed to implement

Team Collaboration. with different views and expertise in seeing and solving the problems of implementing the eye-gaze technology intervention, was recognized as necessary. "When the therapist was in class, we sorted out the problems together. Because there was someone to support, I wasn't so worried when facing a problem" (Teacher 4). Some teachers and therapists noted that the collaboration enhanced their competencies in applying eye-gaze technology in practical work. Participants indicated that technical support and troubleshooting concerning program failure were helpful, and stressed these resources as necessary for future implementation. Some therapists pointed out that follow-up services in supporting parents to expand communication opportunities were critical because they observed that some students used eye-gaze technology for communication less frequently at home.

Device availability and loaning program. During the intervention, the students borrowed the eye-gaze devices for free. Participants said this trial period enhanced their understanding of whether the technology suited the child, but they had to apply for personal eye-gaze devices to allow future use. Parents expressed concerns regarding choosing between various products and how much the additional payment was. "There are different kinds of devices and software. I don't know which one is suitable for her" (Parent 4). They believed that a loaning program for eye-gaze devices could facilitate the implementation, considering the costs of an eye-gaze system and the extended familiarization duration.

In-service education. Participants described education on eye-gaze technology as helpful to increase knowledge and skills but said it was currently lacking in the service systems. Teachers and therapists reported in-service education as essential for improving their self-efficacy. "Because if I know more, the more methods I have to solve the problem, and the more confidence I have to support teachers and parents" (PT1). Some therapists also indicated that the professional education could enhance communication and consensus-building with the AT centers when prescribing a personal device.

Practicality

Ease of carrying out in everyday contexts

Embedding into routine activities and educational plan. Teachers described eye-gaze technology as easier to implement when embedding it into classroom activities, and the technology assisted instruction. Because of insufficient staffing, it was perceived as challenging to do eye-gaze activities as separate training from group activities. In addition, integrating eye-gaze technology into the IEP and treatment plan was recognized as crucial to evaluate progress in regular work without requiring extra effort.

Infrastructure for collaboration. Several participants reported that working in the same unit as teachers and therapists enhanced the practicality of the collaboration. Some therapists found that shared observations with teachers and parents were essential. When they worked in different units, they needed extra time to meet teachers, and perceived challenges in providing support. "In practice, the collaborative service might not be easy to apply, unless the working unit provides adequate working hours and payment" (PT1).

Ability of students to carry out intervention activities

The students' motivation was perceived as paramount for developing competencies and for carrying out activities via eye-gaze technology. Participants were concerned that the students needed an extended time to establish eye control skills and aided communication competencies to use gaze-controlled computers for communication because of their limited experience of eye-pointing communication or using low-tech devices. "Her experience of choice-making was relatively limited, so she had difficulty understanding the link between making choices and their consequences" (OT2). Two therapists reported that the students did not fully understand eye-gaze technology as a communication means, so they did not proactively use it for self-expression as expected.

Some participants mentioned that the students' low eye control skills and visual problems increased challenges in locating an object and making selections via gazing at a screen. "It's not like he doesn't want to look, you can actually see he's really trying, but the problem is he cannot synchronize his eyes and his thoughts" (OT1). The accommodations for picture complexity, color contrast or page arrangement could ease operation of the system. Still, participants found that the students showed familiarity with gaze-computer interaction over time, expanded the visual search area and increased the speed of gaze selection after regular practice.

Some therapists suggested building students' abilities (e.g., longer gaze duration, sense of causality, seating endurance) and choice-making experience in daily contexts to maximize intervention practicality and minimize the implementers' workload and frustration.

Discussion

To the best of our knowledge, this is the first feasibility study to investigate whether an eye-gaze technology intervention works in everyday activities for parents, teachers, and therapists when supporting students to use the technology. This study contributes knowledge on what participants considered acceptable and appropriate in the eye-gaze technology intervention and shows the facilitators and barriers of implementing the intervention in a Taiwanese context. Overall, the intervention was shown to be feasible; however, several barriers in implementation and practicality need to be considered in future interventions.

The findings showed the appropriateness of the technology intervention for offering a better situation for dyadic interactions. The students using eye-gaze technology to provide information and increase the clarity of the communication messages could offer opportunities for their communication partners to better understand their communication intentions. Hence, use of eye-gaze technology reduced some of the necessity for the partners to refer to contextual information to understand students' communicative utterances (Dhondt et al., 2020). Furthermore, the impact of using eye-gaze technology is probably bi-directional or transactional. The students' use of eye-gaze technology to respond to and participate in learning situations could increase the teachers' understanding of their interests and learning situations (Rytterström et al., 2016). As such, teachers could develop more positive attitudes toward the students and build realistic educational goals to facilitate their learning and communication.

The results also indicated the necessity of employing a multimodal approach as the students did not use eye-gaze technology every day, meaning that eye-gaze technology may not be suitable as their sole mode of communication. Analysis of the interviews also suggested combining the use of eye-gaze technology and other means of communication to fulfill various communication needs, a finding that conformed with earlier scholars' recommendations of multimodal communication (Light et al., 2019). Using eye-gaze technology for communication has advantages for autonomous communication and utterance construction (Hsieh et al., 2021), whereas low-tech AAC has the strengths of better portability and convenience for quick communication in various contexts. Concerning different communication purposes and contexts, eye-gaze technology, low-tech and unaided AAC could supplement each other to increase the practicality of everyday communication.

This study identified that time demands posed a barrier for communication partners in supporting students to use eye-gaze technology every day. Introducing the technology might disturb classroom or family routines and reduce time available for teachers and parents to do other work. To increase the feasibility of everyday use, future interventions need to consider how to alleviate the effort required for implementation.

The results showed that the participants were less satisfied with the adjustment of the eye-gaze systems, which was also highlighted in the interviews that an added-on eye-gaze device connected to a laptop mounted by a table stand was inconvenient to transport. This aligned with an earlier report which found that the teachers might take a longer time for set up, adjustment, and calibration for an add-on system than a built-in system, although both had comparable accuracy (Lui et al., 2022). A portable eye-gaze system could enhance the practicality of using a computer across contexts; however, affordability might be a concern when choosing integrated and portable systems. In Taiwan, there was an upper limit of funding support for eye-gaze devices.

This study confirmed that tailored content and regular updating with appropriate symbols, vocabulary, and layouts to each student's needs were critical for student-centered eye-gaze technology implementation (Holmqvist et al., 2018; Karlsson et al., 2021). However, the interviews revealed that modifying the content to meet the student's progress and changing needs was time-demanding. This highlights the need for further improvement in terms of easily expandable content, less complex inter-page links, and continuous technical support for content modification in future implementations. Practicality could be enhanced by developing templates tailored to the education curriculum and the cultural context and guidelines for adjusting the communication pages. In addition, previous studies have indicated that communication partner strategies and training are crucial to scaffold the student's successful use of aided AAC (Kent-Walsh et al., 2015; Tegler et al., 2020). Therefore, continuous on-site training for communication partners to manage the communication program better and integrate communication opportunities into routines is necessary in future interventions to support the effective utilization of eye-gaze technology as a communication means.

Regarding the resources for implementation, the findings highlighted that a loaning program to trial eye-gaze systems (e.g., device, software, and mounting system) was crucial but currently lacking in AT systems. An earlier study on eye-gaze technology clinical guidelines has suggested a trial period to evaluate whether the technology matches the student's needs and is convenient to use (Karlsson et al., 2021). Students with severe disabilities might take an extended time to become familiar with eye-gaze systems (Borgestig et al., 2017; Hsieh et al., 2022). Implementing a loaning program in AT services to trial eye-gaze devices could be highly beneficial to enhance technology-student matches and minimize wastage of AT resources.

The integrated findings from participants' satisfaction reports and interviews confirmed that professional services are important facilitators for personalized eye-gaze implementation, in accordance with the recommendation from earlier studies (Karlsson et al., 2021; Perfect et al., 2020); however, follow-up services and in-service education on eye-gaze technology are currently lacking within the AT service systems in Taiwan. In practical settings, low collaboration frequencies when school teachers and therapists work in different units could impede joint problem-solving and the adaptation of activities to meet students' needs, abilities and interests. Moreover, insufficient in-service education could undermine the professionals' abilities to identify students who would potentially benefit from the technology and to update the intervention plan to maximize the potential of using the technology for students' participation (Moorcroft et al., 2019; Tsai, 2019). Therefore, a flexible infrastructure to foster regular team services and developing in-service education through professional training and exchanges of service experiences of eye-gaze technology is paramount for sustainable implementation.

Regarding practicality, this study indicated that students' insufficient eye control skills and aided communication experiences might increase challenges in guiding their use of eye-gaze technology. Nevertheless, the interviews also showed that the students could develop their eye control skills with extended practice on steering a computer via eye-gaze, confirming the learnability for students with severe disabilities (Borgestig et al., 2017, 2021). Students with severe motor and communication difficulties should not be excluded from trying eye-gaze technology if they have restricted use of other access methods. A preparation phase to build eye-pointing and choice-making experiences in communication (Karlsson et al., 2021) could be practical for accelerating the learning process of operating a gaze-controlled computer and reducing the partner's burden for providing guidance.

Some current results align with earlier reports from Western countries regarding factors associated with AAC acceptance or abandonment (Johnson et al., 2006; Moorcroft et al., 2019). Common barriers identified include system features and fit (e.g., difficulty in adjustment, lack of updated content to meet user's needs), support networks and services (e.g., lack of partnership among key stakeholders and follow-up services), time demands of communication partners, and lack of professional training. These findings suggest universal factors influencing AT implementation across cultures. Based on a Taiwanese context, this study pointed out the importance of shared observations in team collaboration and integrating eye-gaze technology into educational plans. It underscored the value of a loaning program to trial and evaluate technology appropriate to the students' needs. Furthermore, developing students' eye-pointing communication skills, along with their seating endurance, can enhance the implementation of eye-gaze technology.

Clinical implications

Communication partners play crucial roles in facilitating computer use and increasing communication opportunities via eye-gaze technology. Time demands faced by communication partners may affect the availability of opportunities to maximize the utilization of eye gaze technology. To ensure effective implementation and use of this technology in different contexts, it is crucial to provide continuous team services when tailoring computer content and communication strategies. In-service education for professionals is critical for high quality, student-centered AT services and for technology uptake.

Limitations and future directions

One limitation is that the first author was involved in both the intervention and the data collection from interviews. The researcher's role in providing initial education for participants and supporting therapists might have influenced their responses (Kvale & Brinkmann, 2015). However, given that the development of eye-gaze technology for students with severe disabilities was relatively new in Taiwan, it was practical and necessary for the researcher to be involved in some steps of the intervention. The participants described both the facilitators and barriers in implementing the eye-gaze intervention; thus, the response bias was assumed to be minimal.

This study has limited transferability due to the small samples. Nevertheless, as a feasibility study, it can shed light on improving eye-gaze technology intervention for a future large-scale study (Bowen et al., 2009; Orsmond & Chon, 2015). The sampling methods, inclusion criteria, participants' characteristics, and the procedure of this study were reported for scholars to refer to when extending the results to their own situations.

Further research, including a follow-up period to investigate the students' long-term use of eye-gaze technology, is recommended, taking account of the different viewpoints on the future use and the identified barriers. The barriers the students and communication partners face in different phases of using eye gaze technology will provide valuable insights into the sustainability of implementation.

This study did not collect the subjective perspectives of the students, as it was challenging to employ appropriate methods for collecting their subjective experiences of participation due to their severe motor and communication difficulties. However, while the students learned to use eye-gaze technology for communication, the technology shows potential for future researchers to gather the students' perspectives with carefully designed content.

Conclusion

This feasibility study has identified essential factors facilitating or hindering the use of eye-gaze technology that could help scholars improve the design of the intervention for further examination of its effectiveness. Moreover, the work could serve as a knowledge base for practitioners when planning the intervention.

This work shows that the eye-gaze technology intervention was appropriate for increasing the autonomy and initiative of students with severe motor and communication difficulties and for facilitating interaction and communication partners' understanding of the students' learning and communication messages. To enhance the implementation, improving transportability, adjustments of eye-gaze systems and ease of page modification were crucial. Follow-up services and education on knowledge and skills of eye-gaze technology helped communication partners to guide the students in utilizing the technology for participation and communication. Furthermore, the AT service infrastructure requires flexibility in order to develop a loaning program for eye-gaze devices, offer in-service education, and foster team collaboration for sustainable implementation.

Notes

1. Tobii PCEye Mini is an eye-gaze product of Tobii Dynavox Ltd. https://us.tobiidynavox.com/
2. HelpKidzLearn is a game software of Inclusive Technology Ltd. https://www.helpkidzlearn.com/
3. Communicator 5 is a communication software of Tobii Dynavox Ltd.

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ORCID

Yu-Hsin Hsieh http://orcid.org/0000-0002-6220-2340
Mats Granlund http://orcid.org/0000-0001-9597-039X
Helena Hemmingsson http://orcid.org/0000-0003-1281-6392

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