Teleintervention for users of augmentative and alternative communication devices

Bekteshi, Saranda; Konings, Marco; Karlsson, Petra; Criekinge, Tamaya Van; Dan, Bernard; Monbaliu, Elegast

Published in:
Developmental Medicine and Child Neurology

DOI:
10.1111/dmcn.15387

Publication date:
2023

License:
Unspecified

Document Version:
Accepted author manuscript

Teleintervention for users of augmentative and alternative communication (AAC) devices: a systematic review

Saranda Bekteshi[1*], Marco Konings[1], Petra Karlsson[2], Tamaya Van Criekinge[3], Bernard Dan[4], Elegast Monbaliu[1]

[1]KU Leuven, Bruges Campus, Department of Rehabilitation Sciences, Research Group for Neurorehabilitation, 8200 Bruges, Belgium; [2]University of Sydney, Cerebral Palsy Alliance, Sydney, Australia; [3]KU Leuven, Bruges Campus, Department of Rehabilitation Sciences, Musculoskeletal Research Group, 8200 Bruges, Belgium; [4]Faculty of Medicine, Université Libre de Bruxelles, Brussels, Belgium

Corresponding author: Saranda Bekteshi, KU Leuven, Bruges Campus, Department of Rehabilitation Sciences, Research Group for Neurorehabilitation, 8200 Bruges, Belgium

Email: saranda.bekteshi@kuleuven.be

Abbreviations

AAC – Augmentative and Alternative Communication

ALSFRS-R – Amyotrophic Lateral Sclerosis Functional Rating Scale-Revised

ASHA - American Speech-Language-Hearing Association

ATDPA – Assistive Technology Device Predisposition Assessment

BCI – Brain-Computer Interface

BLAF – Behavioral Language Assessment Form

EACS – Edinburgh Cognitive and Behavioral Amyotrophic Lateral Sclerosis Screen

FA – Functional Assessment

FCT – Functional Communication Training

ROBINS-I - Risk of Bias in Non-randomized Studies-of Intervention

SCED Scale – Single-Case Experimental Design Scale

SCD RoB – Single-Case Design Risk of Bias

SDA – Structured Descriptive Assessment

SGD – Speech Generating Device

SLP – Speech-Language Pathology

SWiM – Synthesis Without Meta-analysis

TARF-R - Treatment Acceptability Rating Form-Revised

VABS - Vineland Adaptive Behavior Scales

Abstract

AIM: To synthesize existing evidence on the effectiveness of speech-language teleinterventions delivered via videoconferencing to users of Augmentative and Alternative Communication (AAC) devices.

METHOD: A systematic literature search was conducted in ten electronic databases, from inception until August 2021. Included were speech-language teleinterventions delivered by researchers and/or clinicians via videoconferencing to users of AAC devices, without restrictions on chronological age and clinical diagnosis. The quality of the included studies was appraised using the Downs and Black's checklist and the Single-Case Experimental Design (SCED) Scale, and risk of bias was assessed using the Risk Of Bias In Non-randomized Studies-of Interventions (ROBINS-I) and the Single-Case Design Risk of Bias (SCD RoB) tool.

RESULTS: Six teleinterventions including 25 participants with a variety of conditions, like Down Syndrome, Autism, Rett Syndrome, and Amyotrophic Lateral Sclerosis met the inclusion criteria. Five studies used a single-case experimental design and one was a cohort study. Teleinterventions included Active Consultation (n=2), Functional Communication Training (n=2), Brain-Computer Interface (n=1), and both tele- and in-person intervention (n=1). All teleinterventions reported an increase in participants' independent use of AAC devices during the training sessions compared to baseline, and an overall high satisfaction and treatment acceptability.

INTERPRETATION: Speech-language teleinterventions for users of AAC devices show great potential for a successful method of service delivery. Future telehealth studies with larger sample sizes and more robust methodology are strongly encouraged to allow the generalization of results across different populations.

What this paper adds:

1. Individuals can learn to use AAC devices independently during tele-AAC interventions.
2. Service providers and recipients reported an overall high satisfaction and acceptability for AAC services delivered via teleinterventions.
3. Speech-language teleinterventions may be an effective method of providing AAC intervention services.

Speech and language impairments affect the ability to talk, read, write, and at times be understood. The impairments may range from a few sound errors to a complete inability to communicate effectively.[1] Speech-language skills are a predictor of the level of independent living, achievements in education, increased social participation, and higher employment opportunities.[2, 3] Early and continuous provision of speech-language pathology (SLP) services is essential, especially since the majority of children receiving SLP services are in the critical period of their speech and language development, often referred to as the "golden age".[4, 5] Thereby, any disruption in this early and continuous provision of SLP services may lead to chronic and irreversible speech-language impairments, which are additionally related to both cognitive and physical development, all impacting the quality of life.[4]

In spite of efforts to make healthcare services accessible to everyone, the World Report on Disability[6] acknowledges the 'medically under-served populations' who face numerous barriers to access healthcare, including SLP services. Barriers include a lack of health workforce to meet population needs and structural, geographical, financial, linguistic, or cultural barriers.[7] As such, technological advances and evolving healthcare policies to facilitate remote service delivery have been widely adopted to increase accessibility and optimize healthcare outcomes.[8] Recently, the COVID-19 pandemic rapidly and drastically required the shift of healthcare services from face-to-face delivery to telepractice modalities.[9, 10] This was a key strategy to maintain and complement healthcare services disrupted by the pandemic, revealing the need for a higher emphasis on telepractice in speech-language-hearing services.[4]

The American Speech-Language-Hearing Association (ASHA) defines telepractice as "the application of telecommunications technology to the delivery of SLP and audiology professional services at a distance by linking clinician to client or clinician to clinician for assessment, intervention, and/or consultation".[11] Telepractice is shown to be a feasible, effective, and appropriate method to deliver remote SLP services as it increases the accessibility of services to clients who live in remote, rural, underserved areas, it prevents unnecessary delays in receiving care, it reduces travel-burden, especially for people with mobility limitations and aging populations, and it is a time- and cost-efficient service delivery.[12-14] This remote service delivery can be asynchronous (i.e., a store-and-forward method using pre-recorded online material for viewing, training, or interpretation by professionals) and synchronous (i.e., client interactive method with real-time feedback and exchange of information using videoconferencing).[11, 14] Telepractice is interchangeably referred to as telehealth, telerehabilitation, telemedicine, telespeech, telecommunication, or eHealth.[8]

An overview of telepractice in SLP reports shows its applicability over a wide age range (from children to seniors), various speech-language impairments (like fluency, voice disorders, neurogenic communication disorders, childhood speech and language disorders), characterizing several clinical diagnoses (such as acquired brain injuries, neurodegenerative diseases, and neurodevelopmental disorders).[1, 15] Telepractice can be used to deliver a number of SLP services, ranging from evaluation, assessment, consultation, monitoring, rehabilitation, Augmentative and Alternative Communication (AAC), and intervention.[8, 12] Systematic reviews synthesizing current evidence in teleinterventions[16] are particularly useful to facilitate a rapid transitioning to telepractice delivery.[12]

Numerous systematic reviews[2, 17-27] synthesized existing evidence in speech-language teleinterventions, mainly focusing on speech and language interventions (i.e., vocalization and verbalization) such as fluency, accuracy in reading, naming, and spelling, language production and

comprehension, speech intelligibility, or accurate articulation. Synthesized evidence is, however, lacking in populations who use AAC devices as their primary means of communication. AAC devices are defined as "any method of communicating that supplements (augments) or replaces (provides an alternative to) the usual methods of speech and/or writing where these are impaired or insufficient to meet the individual's needs".[28] AAC devices have the potential to enhance communication, language, and literacy development for people with complex communication needs[29] leading to increased access to their environment, social participation and increased opportunities for better language and literacy outcomes.[30] AAC modes can be unaided (gestures, body language) and aided, which ranges from non-technology (picture symbols and books) to technology AAC devices like speech-generating devices (SGD), voice-output software, eye-trackers, brain-computer interfaces (BCI), and others.[31] Official reports on the number of people who rely on the daily use of AAC devices indicate an estimated prevalence of 0.5% of the British population (536/100000 people)[32] and 1.3% of the American population (around 4 million).[33] The estimated prevalence is on the rise worldwide[31], with people with different clinical diagnoses benefiting from AAC devices, ranging from brain insults to progressive diseases, genetic syndromes, and neuromuscular diseases, among others.[34]

Two systematic reviews[35, 36] synthesized evidence of teleinterventions in users of AAC devices, namely in individuals with developmental disabilities[35] and in children with autism[36]. Both reviews focused on family-implemented social and communication interventions in which communication partners were trained through online instructional courses and/or videoconferencing to implement the respective home-based intervention. Although family-implemented interventions in users of AAC devices are reported to be successful[35, 36], they require careful planning, and communication partners usually complete their training independently at a convenient time, possibly delaying the provision of early speech-language intervention. Synthesized evidence of teleinterventions provided directly to the user of AAC devices by experts such as speech-language therapists or clinical researchers is currently lacking. Law et al.,[37] recently synthesized the existing reviews on telepractice interventions for children and young people with communication disabilities. Out of ten included reviews, none reported the use of telepractice for AAC interventions.[37] Given the importance of the early provision of speech-language interventions, the ever-growing potential of telepractice as a method of service delivery, and the lack thereof of synthesized evidence on synchronous teleinterventions for AAC users, this systematic review aims to answer the following research question: "How are speech-language teleinterventions provided to users of AAC devices, and what is their effectiveness on the use of AAC devices and participants' overall communication competences?"

Methodology

The systematic review was organized and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[38] guidelines and was prospectively registered with PROSPERO (CRD42021231913). Minor changes were made to the registered protocol on 23 August 2021. Changes included (1) changing the 'comparator' section in the PROSPERO record from 'Not applicable' to 'Any comparator (like non-exposure control group or an on-site AAC intervention) or lack of comparator will be included', an amendment which better satisfied the four PICO elements, 2) an update to include both English and non-English language records. The A MeaSurement Tool to Assess systematic Reviews-2 (AMSTAR-2) checklist was used for the critical appraisal of this review.[39]

Search strategy

A primary literature search was performed by one author (SB) in ten electronic databases, including Embase, Medline (Ovid), ProQuest, Web of Science, PubMed, Scopus, CINAHL (EBSCO), Cochrane Library, PEDro, American Speech-Language-Hearing Association (ASHA) journals from intercept to 16th of August 2021. No restrictions were set on publication language; retrieved were all records in English and non-English languages. Additionally, Google Scholar was manually searched using the pre-determined search terms.

Search terms included different variations of keywords, including a combination of the 1) method of intervention delivery (telerehabilit* OR telepractice OR telehealth OR telemedicine OR tele-aac OR remote communication OR internet-based OR web-based OR e-rehabilit* OR e-health OR videoconferenc*) and 2) intervention of interest ('augmentative and alternative communication' OR AAC or alternative computer access OR speech-generating devic* OR speech-language). Search strategies with controlled terms for Medical Subject Heading (MeSH) resulted in the majority of keywords ignored (such as telepractice, telehealth, tele-aac, internet-based, web-based, augmentative and alternative communication, alternative computer access, speech-language, and others), thus, MeSH terms were not included. The search strategy in all databases is shown in Supplementary file S1.

Deduplication was done using EndNote reference manager software, version x9 (Clarivate Analytics, Philadelphia, PA, USA). After the de-duplication, the final records were imported into Rayyan – Qatar Computing Institute Research (QCRI)[40] for screening and labeling.

Inclusion and exclusion criteria

Inclusion criteria were: 1) speech-language teleintervention studies that were done live and remotely, that is, real-time feedback during intervention sessions by a researcher or a clinician (herein referred to as 'coach'), 2) targeting low-tech or high-tech AAC users, i.e., all AAC devices from 2D cards to eye-tracking technology and BCI, excluding unaided AAC like the use of body parts to communicate, and 3) peer-reviewed journal publications. No restrictions were set on chronological age and clinical diagnosis. Both Randomized Controlled Trials (RCT) and Non-randomized Studies of Interventions (NRSI) were considered for inclusion because these most clearly represent the available literature. To summarize following the PICO (population, intervention, comparator, outcome) principles, this systematic review will focus on AAC users (P) receiving a tele-AAC intervention with real-time feedback by a coach (I), which may be compared to a non-exposure control group, an in-person AAC intervention or lack a comparator (C), aiming to improve communication competences (O).

Exclusion criteria were: 1) home-based interventions implemented by the parents of the AAC user without real-time videoconferencing involvement of a coach during the intervention sessions, that is, interventions in which parents were trained asynchronously through online modules before the start of the intervention, 2) teleinterventions with no AAC device (such as vocal or verbal training for people with aphasia or stroke).

Selection procedure

The initial screening of titles and abstracts was done independently by two authors (SB and MK). Both authors had separate password-protected access to Rayyan where a possibility is given to label records as 'exclude', 'maybe', or 'include'. When in doubt, studies were included for full-text reading to ensure that no relevant studies were excluded. Most of the non-English records had an abstract available in

English. The records without an English abstract were translated using Google Translate.[41, 42] The initial screening of titles and abstracts was discussed, and an agreement was reached regarding the included records for full-text review. The procedure was then repeated. Both authors independently read the full-text records, and each made an inclusion or exclusion decision. Google Translate was used to translate the non-English records included for full-text review. Reference lists were manually searched for any additional publications of interest. Any disagreement about the eligibility of the final records to be included in the systematic review was resolved by a consensus meeting.

Data extraction

Data were extracted using an Excel spreadsheet, and it included: 1) study ID (title, author, year), 2) participant characteristics (age, sex, diagnosis, AAC technology), 3) study characteristics: ((study design, aims, study phases (baseline, intervention, follow-up), duration, interventionist, tele-technology, outcome measures, statistical analyses, and funding sources)), and 4) results and conclusions. Data extraction was done by one reviewer (SB) and thoroughly checked by a second reviewer (TVC), followed by a discussion in which a 100% agreement was reached due to consensus-building.

Study quality appraisal and risk of bias assessment

A methodological quality appraisal and a risk of bias (RoB) assessment were performed independently by two authors (SB and MK) for each included study. A 100% agreement was reached as a result of consensus-building.

Two separate tools were used to appraise the quality of evidence for the cohort study and the single-case experimental design studies, respectively. The cohort study quality appraisal was done using the modified version of Downs and Black's quality assessment checklist[43], which has shown a high internal consistency, good test-retest and inter-rater reliability, and good face and criterion validity in non-randomized studies.[43, 44] The checklist includes 27 quality items across five subscales, including reporting (n=10), external validity (n=3), internal validity-bias (n=7), internal validity-confounding (n=6) and power (n=1). Out of the checklist, 25 quality items have a total possible score of 1, with score 1 representing adequate quality and score 0 representing no adequate quality or quality unable to be determined. The 26th item (item 5) has a total possible score of 2, and the 27th item (item 27) is scored on a scale that ranges from 0 to 5. Thereby, the total possible score of the quality items is 32, with a higher score indicating better methodological quality. Quality levels were used as reported by Hooper et al.[45]: excellent (26-32); good (20-25); fair (15-19); and poor (≤14). The methodological appraisal of the single-case experimental design studies was done using the Single-Case Experimental Design (SCED) Scale[46], an 11-item scale that has shown excellent inter-rater reliability using both individual and consensus ratings.[46, 47] The quality items included in the SCED Scale are: 1) clinical history, 2) target behaviors, 3) study design, 4) sufficient baseline measures, 5) sampling behavior during treatment, 6) raw data recorded, 7) inter-rater reliability, 8) independence of assessors, 9) statistical analysis, 10) replication and 11) generalization. The maximum score of the SCED Scale is 10/10, indicating the highest methodological quality, whereas scores 0-4 indicate weak quality of evidence, scores 5-7 indicate a moderate quality of evidence, and scores 8-10 indicate a high quality of evidence. Quality items were scored using 1 as yes (present) and 0 as no (absent). In the SCED Scale, question 1 (i.e., clinical history) does not contribute to the total score.

Depending on the study design, two separate tools were used to assess the RoB of the included studies, that is, the Cochrane's Risk of Bias in Non-randomized Studies-of Intervention (ROBINS-I) assessment tool[48] and the Single-Case Design Risk of Bias (SCD RoB) tool[49]. ROBINS-I assesses RoB across eight domains, including bias due to confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported results. An overall RoB for each study can be low, moderate, serious, critical, or no information. The SCD RoB is an adaptation of Cochrane's RoB tool to specifically assess RoB in studies with single-case experimental design. The SCD RoB tool assesses each study for: 1) selection bias (sequence generation and participant selection), 2) performance bias (blinding of participants and personnel, and procedural fidelity), and 3) detection bias (blinding of outcome assessors, selective outcome reporting, dependent variable reliability and data sampling). The RoB for each of these criteria is reported as low risk, unclear risk or high risk.

Data synthesis and reporting

The small number of included studies and the heterogeneity in population, lack of consistent outcome measures, and the small number of participants may preclude any meaningful meta-analysis and make any results unhelpful for clinical practice. Therefore, a formal narrative synthesis was conducted using the Synthesis Without Meta-analysis (SWiM) reporting guidelines.[50] Data was grouped based on participant characteristics, study characteristics, and outcome measures. Standardized metrics were explained for each outcome measure, and reporting of study findings was prioritized based on the relevance of evidence pertaining to the review question, study appraisal quality, and/or risk of bias assessment. Tables and graphs were used to present the findings. To facilitate comparisons, in-text results are reported as percentages of the maximum score for each outcome measure, whereas the tables contain the actual scores (as reported in the original studies).

Results

Search results

References yielded during the database search and the subsequent stages of the review are summarized in a PRISMA flow diagram (Figure 1). A total of 4718 records were identified (n=4637 in English and n=81 in non-English) during the database search, and additional 35 records through other sources (i.e., manually searched Google Scholar and reference lists). After de-duplication, the titles and abstracts of 3628 records were screened, where 3524 (n=3465 in English and n=59 in non-English) of these records were excluded. The remaining 104 records (n=93 in English and n=11 in non-English) were retrieved for full-text review. After full-text review, 98 records were excluded due to lack of teleinterventions and/or lack of AAC and/or SGD outcome measures. The excluded records and corresponding justification are reported in Supplementary file S2. Six teleintervention studies[51-56] for AAC users met the eligibility criteria for inclusion in this systematic review.

Participant characteristics

Six studies included a total of 25 participants and were highly variable across diagnosis and age (Table 1). Out of the 25 participants, 12 (48%) were diagnosed with Amyotrophic Lateral Sclerosis (ALS), five (20%) with ASD, two (8%) with Down Syndrome, and one participant each (24%) with Mitochondrial Myopathy, Developmental Delay, Primary Later Sclerosis (PLS), Progressive Muscular Atrophy (PMA), Schizoencephaly, and Rett Syndrome. Age ranged from 3.5 years to 63.7±8.2 years, with 18 (72%) male

participants. Two studies[51, 55] defined their participants with 'significant expressive language deficits,' but no reliable assessment scales were reported. Seven participants[52, 53, 56] were assessed with low adaptive levels based on the Vineland Adaptive Behavior Scales (VABS).[57] Four participants[52] were evaluated with the Behavioral Language Assessment Form (BLAF)[58], in which all four participants scored 1 (i.e., the lowest score) in the receptive and conversation skills domains. Participants from the teleBCI study[54] were assessed for severity of diagnosis (n=14 participants) using the ALS Functional Rating Scale-Revised (ALSFRS-R)[59] and for cognitive and behavioral impairments (n=9) using the Edinburgh Cognitive and Behavioral ALS Screen (ECAS)[60], based on which one participant had both cognitive and behavioral impairments, and two additional participants showed only behavioral impairments. The AAC technology used by the participants ranged from low-tech to high-tech and is listed in Table 1.

Study characteristics

Five studies used a single-case experimental design[51-53, 55, 56] and one was a cohort study.[54] Of the single-case experimental design studies, two used an AB design[51, 55], two used an ABAB design with returning baseline and intervention phases[53, 56], and one used an ABABC design[52] with a follow-up one-month post-intervention (Table 2). The cohort study used an AB design.[54] The duration of the studies ranged between 9 and 69 sessions, from 30 minutes to 90 minutes per day, from 7 weeks to 23 weeks. Intervention sessions were scheduled once a week[54, 55], 2-3 times a week[51-53], or daily[56], with training organized either as a single session per day or as intermittent block sessions (i.e., mini-sessions spread throughout the day). Two studies[51, 52] delivered the teleintervention through an Active Consultation, an indirect delivery strategy combining Bluetooth technology and videoconferencing software to provide real-time feedback to the in-person interventionist. Two studies[53, 56] focused on Functional Communication Training (FCT) delivered via videoconferencing. FCT is defined as a behavioral therapy for children with developmental disabilities which aims to teach an alternative and recognizable form of communication (i.e., AAC, manual signs) as a substitute for an idiosyncratic response (i.e., unique responses like tantrum, crying, reaching).[61, 62] One study[55] compared both in-person and teleintervention delivery method and one study[54] focused on BCI intervention delivered via videoconferencing (i.e., teleBCI). Four studies[53-56] delivered the teleintervention at the participant's home, one at a university room[51], and one at the participant's classroom[52]. The interventionists and the teleintervention technology are described in Table 2.

Outcome measures

The outcome measures of each study are reported in Table 2.

Boisvert et al.[51] reported the frequency count of the produced number of phrases and varied phrases by both the pre-professional (a graduate student) and the participant. A phrase was defined as one or more sequential symbol selections where each symbol represented a word. An increase in frequency count by the pre-professional indicated increased support provided to the participant, whereas an increase in frequency count by the participant indicated increased independent use of the SGD. In addition, Boisvert et al.[51] included a Likert-scale survey with six questions, aiming at exploring the feasibility and social validity of the Active Consultation as a method to supervise and/or train. The survey was filled in by the pre-professional after each intervention session.

The study by Carnett et al.[52] included two intervention phases: Phase 1 aimed at increasing participants' independent activation of SGD, whereas phase 2 aimed at independent activation of SGD combined with a choice of preferred and non-preferred items to assess correspondence. The dependent variable in both intervention phases was the frequency of independent SGD activations by pressing the symbol to activate the synthesized speech. Carnett et al.[52] reported teacher's fidelity to the communication interventions, defined by the frequency of independent use of eight teaching procedures during the intervention sessions, such as assessment of each participant for preferred items, ensuring the SGD is programmed with the corresponding item, using most-to-least prompting, and others. Interobserver agreement was calculated for 40% of the baseline data, and 30-33% of the videotaped intervention sessions. Satisfaction with the teleintervention was assessed using the Treatment Acceptability Rating Form-Revised (TARF-R)[63], a 20-item rating questionnaire adapted to include telehealth components, filled in by the teachers pre- and post-intervention.

Dimian et al.[53] identified *play, help,* and *break* as contexts for both participants to train an independent use of superordinate and subordinate page-sets in their SGD. Superordinate pages refer to grouping vocabulary in the SGD based on mutual characteristics such as food or play. After selecting one group (for example, food), a subordinate page appears with more symbols/choices corresponding to the respective vocabulary group (for example, drinks or snacks). Authors reported the frequency of idiosyncratic responses (i.e., reaching or pointing, tantrum, vocalizations, pulling away, and others) and the frequency of AAC symbol production that produced a voice output message. In addition, authors reported the caregivers' fidelity to communication interventions, defined by the frequency of correctly using predefined coaching strategies. Interobserver agreement was calculated for at least 35-40% of all videotaped sessions. Satisfaction with the teleintervention (i.e., social validity ratings of the interventions) was assessed using the TARF-R.

Geronimo and Simmons[54] used videoconferencing (i.e., teleBCI) as a delivery method of training, looking at communication accuracy (i.e., >70% correct selections of randomly chosen words from a predefined word bank) and selection bit rate (i.e., derived from bits per selection and divided by trial length). Authors also reported the progress from the use of "training program" with pre-determined words/phrases to "notepad speller", in which the participants could spell their own words/phrases. In addition, Geronimo and Simmons[54] reported the Assistive Technology Device Predisposition Assessment (ATDPA) form of the Matching Person and Technology (MTP) assessment[64], filled in by the participants' support network at the first and last session. ATDPA aimed to explore the functionality of the tele-BCI to the user's communication needs in 12 domains, rated on a 1-5 scale, with a total score of 60 indicating maximum expected benefit.

Hall et al.[55] explored training of grammatical morphemes *ed, ing,* and *plural-s* to an SGD user through two delivery methods: 1) in-person AAC intervention and 2) teleintervention via videoconferencing. The dependent variables in the study were the frequency of correct use of the grammatical morphemes and the frequency of each morpheme's use between prompted and independent responses. The independent variables were the method of service delivery, that is, in-person AAC intervention service and teleintervention.

Simacek et al.[56] identified three different meaningful contexts per participant (described in Table 3), aiming at providing differential reinforcement for an AAC request in the identified communicative contexts. Similar to Dimian et al.,[53] authors reported the frequency of idiosyncratic responses (i.e.,

reaching, clapping, tantrums, hitting the tray, and others) and the frequency of AAC responses, such as touching a microswitch to activate voice output. In addition, authors reported the caregivers' fidelity to study procedures, defined by the frequency of correctly following six and seven predefined steps for the baseline and the teleintervention, respectively. Interobserver agreement was coded for 25-30% of randomly selected videotaped sessions. Satisfaction with the teleintervention was assessed using the TARF-R, a questionnaire consisting of 17 items related to parent's perception of acceptability and 3 items related to parent's perception of the problem. The TARF-R was slightly modified to include the term "communication".

Study quality appraisal and risk of bias assessment

The Downs and Black's checklist is shown in Supplementary file S3, and the SCED Scale is in Supplementary file S4. The ROBINS-I assessment is shown in Supplementary file S5, and the SCD RoB tool is in Supplementary file S6.

The quality of evidence (Downs and Black's checklist) of the Geronimo and Simmons cohort study[54] was rated as fair with 17 points out of the maximum 32. The lowest quality in this study seems to be in the external validity and the internal validity-confounding (selection bias), whereas the study scored the highest in statistical power (5/5). For the latter (item 27 "power"), the highest possible score of 5 is given to studies with n8+ (i.e., a sample size consisting of more than eight participants). The study by Geronimo and Simmons[54] included 14 participants, therefore scoring 5/5 in statistical power. Based on the ROBINS-I, the cohort study had a 'serious RoB', which indicates the presence of important methodological issues, mainly due to serious RoB in the measurement of outcomes post-intervention.

The quality of evidence (SCED Scale) of the single-case experimental design studies ranged from 3/10 to 8/10, indicating a weak to high quality of evidence. Boisvert et al.[51] and Hall et al.[55] showed weak quality of evidence with the lowest scores in inter-rater reliability, independence of assessors, replication, and generalization. Dimian et al.,[53] Simacek et al.,[56] and Carnett et al.[52] showed moderate quality of evidence with the lowest scores in the independence of assessors, statistical analysis, and generalization. All single-case experimental design studies scored maximum in target behavior and zero in the independence of assessors and generalization. Based on the SCD RoB, the lowest RoB in all included studies was seen in the participant selection and selective outcome reporting. In contrast, the highest RoB was seen in the blinding of participants and personnel and the blinding of outcome assessors.

Synthesis of results

Active Consultation

Two studies[51, 52] delivered the teleintervention through Active Consultation, with pre-professional/teachers serving as interventionists and senior-professional/researchers as coaches to the interventionists. During the intervention sessions, the coaches gave real-time feedback to the interventionists using a Bluetooth connection while simultaneously observing the session via videoconferencing. Results are presented by outcome measure in Table 3.

Boisvert et al.[51] implemented an evidence-based intervention strategy known as aided language stimulation/modeling. Aided language stimulation is a strategy in which communication partners

model language and communication to the child by using the same AAC device used during their interactions.[65] During the first training session (S1), a total of 129 phrases and 4 varied phrases were produced. The pre-professional produced 65.9% of the total number of phrases and 50% of the total number of varied phrases, whereas the participant independently produced 34.1% of the total number of phrases and 50% of the total number of varied phrases. During the last training session (S8), a total of 124 phrases and 54 varied phrases were produced, from which the pre-professional produced 15.3% of the total number of phrases and 24.1% of the total number of the varied phrases, while the participant produced 84.7% and 75.9%, respectively.

The teleintervention by Carnett et al.[52] is grounded on behavioral skills training, an effective method where specific responses are taught using instructions, modeling, and rehearsal with feedback.[52] Results showed a trend of increased fidelity and SGD independence when the recurring intervention phases were introduced and an overall decrease in both fidelity and independence during the return to baseline. That is, the average fidelity increased by 69% from the first baseline to the first intervention phase, which then decreased by 46% during the second baseline, and lastly increased by 47% during the second intervention phase. Similarly, the average SGD independence increased by 72% from the first baseline to the first intervention phase, with a decrease of 66% during the second baseline, and lastly an increase of 68% during the second intervention phase. Improvements were retained during the 1-month follow-up with an average of 94% in both fidelity and SGD independence.

Functional Communication Training

Two studies[53, 56] focused on FCT as a training method to substitute idiosyncratic communication responses with AAC responses, which was implemented by the parents with real-time feedback by the researchers via videoconferencing. The FCT was individualized for each participant using Structured Descriptive Assessment (SDA) and Functional Assessment (FA) to identify three contexts in which participants used idiosyncratic responses instead of their AAC devices.

Overall, results by Dimian et al.[53] show a decrease in idiosyncratic responses and, consequently, an increase in independent AAC responses once the FCT was introduced. Over the three contexts, the first participant decreased their idiosyncratic responses on average from 30% (first baseline) to 6% (first FCT), while the AAC responses increased from 0.2% to 15%, respectively. Only the *play* context had an additional return to baseline and a reoccurring FCT phase. Similarly, the AAC responses increased from 0% to 19%, then decreased to 4% during the second baseline and increased again to 15% during the second FCT. For the second participant, only the independent AAC responses were reported, which showed an average increase over three contexts from 13% (first baseline) to 43% during the first FCT. Similarly, only the *play* context had a return to baseline and additional two FCTs in which the SGD page-set was adapted by increasing the size of the symbols and optimizing their position to facilitate the participant's visual impairment. The results for this context showed a decrease from the first baseline to the first FCT (24% to 12%), with an increase during the return to the second baseline (49%) and a further increase to 80% and 91% of independent AAC responses once the page-set was optimized (second and third FCT respectively).

Over the three contexts identified by Simacek et al.[56], the first participant showed an average decrease of idiosyncratic responses from 33% (first baseline) to 9% (first FCT) and increased AAC responses from 1% to 44%, respectively. In the first context (*snack/drink*), the AAC responses increased from 1% to

34% (first FCT), further increasing by 9% during the second baseline and then by 12% during the second FCT. The second participant showed an average decrease (over the three contexts) of idiosyncratic responses from 90% to 31% (first FCT), with an increase in AAC responses from 14% to 63%, respectively. During the first context (*food/drink*), a second FCT with 'time-delay' followed the first FCT (without time-delay), followed by a return to a second baseline and a third FCT (without time-delay). Results showed an increase of independent AAC responses by 38% from the first baseline to the first FCT, which increased by 48% once 'time delay was introduced'. Furthermore, the AAC responses decreased by 63% during the return to baseline and increased by 38% during the last FCT. Similarly, over the three contexts, the third participant showed an average decrease in idiosyncratic responses from 38% (first baseline) to 9% (first FCT) and, consequently, an increase in AAC responses from 7% to 41%, respectively. In the first context (*food in a highchair*), the independent AAC responses decreased by 52% from the first FCT to the second baseline and then increased by 19% from the second baseline to the second FCT.

TeleBCI

Results by Geronimo and Simmons[54] suggest that overall, there was an increase of 22% in communication accuracy from baseline to intervention and an increase of 2.8 bits per minute from baseline to intervention. Furthermore, by the end of the intervention, nine of the participants progressed to the "notepad speller" for at least one intervention session. This progress was made after achieving 100% accuracy in the "training program". On average, the "notepad speller" was used 46.8% for text-to-speech, 63.5% for text prediction, and 41.3% for prepared text functions.

In-person vs. Teleintervention

Results by Hall et al.[55] show that accuracy increased on average from 3% (baseline) to 79% (in-person) to 100% (teleintervention), with a statistically non-significant difference between delivery methods. During the in-person intervention, half of the responses were independent (52%), whereas, during teleintervention, the independent responses rose to 95%, a statistically significant difference.

Procedural modifications

Procedural modifications refer to all the changes implemented during the intervention to improve previously reported outcomes.

Carnett et al.,[52] implemented procedural modifications during the second intervention phase for a participant who was not engaging in adequate eye gaze use of his AAC device. These modifications were done by adding a blank symbol that played the role of a distractor icon without synthesizing speech and by instructing their teacher to give vocal "look" prompts whenever the participant failed to gaze at the correct symbol on the screen. With these procedural modifications, teachers' fidelity remained the same as before the modifications (93%), while the participant's independent use of SGD increased from 23% (without "look" prompt) to 100% (with "look" prompt). Dimian et al.[53] implemented procedural modifications during the initial phases of the intervention for a participant with visual impairments to increase accuracy while selecting symbols on the screen. Modifications were made to the page set by increasing the size of the symbols and optimizing their position on the screen. Before the procedural modifications, the independent responses ranged between 0-100%, whereas, after the procedural modifications, they ranged between 60-100%. In the study by Geronimo

and Simmons[54], two participants switched from the visual- to the audio version of the P300 speller because of ineffective visual evoked responses, which switch assisted the progress from the basic speller to the notepad speller (i.e., one of the main aims of the teleintervention).

Satisfaction with teleintervention

Five studies[51-54, 56] explored satisfaction with teleintervention and treatment acceptability. Overall, results show high fidelity during the intervention phases, with an average of 93% across studies. The pre-professional[51] reported an average satisfaction with Active Consultation as a service delivery method of 4.8/5 across the eight training sessions. In the study by Geronimo and Simmons[54], the ATDPA decreased by 5.2% from the first to the last training session. This decrease is attributed to the perceived device burden, i.e., BCI fitting into a routine, having the stamina to use BCI, having the necessary support, and fitting in the home. Carnett et al.[52] reported an average decrease of 0.25 from pre-TARF-R (4.17) to post-TARF-R (3.92), indicating a decline in satisfaction that was attributed to the possibility that the intervention interfered with daily routines (i.e., a barrier to skill maintenance in practical settings). Dimian et al.[53] and Simacek et al.[56] assessed the TARF-R only post-intervention and reported it as "highly acceptable" treatment rating.

Discussion

Teleinterventions show potential as an effective method for healthcare delivery that may also help optimize SLP intervention outcomes for underserved populations. This is an important issue that was further highlighted by the Covid-19 pandemic. This systematic review synthesized the existing evidence about tele-AAC interventions delivered to the AAC user via videoconferencing.

Six tele-AAC interventions were provided to twenty-five AAC users with a wide range in age and types of AAC technology and various clinical diagnoses. Overall, the current systematic review may indicate the possibility of implementing tele-AAC interventions with AAC users of different ages and abilities, from non-tech to high-tech AAC devices. However, it is essential to emphasize that five of the included studies are single-case experimental design studies that tailored each tele-AAC intervention to the users' abilities and communication needs, making the generalization of the results challenging. All participants underwent a functional assessment before the intervention, which is a critical step to inform the unique communication challenges they each face and thereby maximize the tele-AAC intervention's efficiency. Furthermore, procedural modifications during the intervention itself may be necessary for AAC users with more severe limitations, which is something to consider when setting up a tele-AAC intervention. Severe visual impairments seem to be one of the main reasons for requiring these procedural modifications.[52-54] For a participant with severe visual impairments[52], incorporating a verbal 'look prompt' during the second intervention phase increased the independent SGD use by 73% compared to the intervention phase without the verbal 'look prompt'. Similarly, a participant with visual impairments[53] increased their AAC responses by 28% once the screen layout was adapted by optimizing the placements of the icons. Additional two participants[54] switched from the visual- to the audio version of the P300 speller because of ineffective visual evoked responses, which switch assisted the progress from the basic speller to the notepad speller.

The interventionists in the included studies were pre-professional[51], teachers[52], parents[53, 55, 56], and other communication partners[54]. Carnett et al.,[52] was the only study that implemented a pre-intervention video training module to coach the interventionists on the delivery of the intervention,

plausibly because it involved Active Consultation as a delivery method. Geronimo and Simmons[54] included a home visit before the start of the training sessions in which the highly complex teleBCI set-up was explained to the communication partners. Thus, five studies[51, 53-56] did not include any pre-intervention coaching, which may be for two reasons. First, the teleintervention was delivered in a synchronous manner[53-56] that included real-time coaching and guidance. Second, most of the studies[51-54, 56] included outcome measures to explore the interventionists' fidelity to study procedures, hence their performance being measured alongside the performance of the AAC user. Overall, results show high fidelity during the intervention phases, with an average of 93% across studies. A decrease in fidelity is seen during the return to baseline (after completing an intervention phase), which may indicate the importance of continued support to communication partners. Previous literature also suggests that coaching by researchers or clinicians ensures better implementation of home training for AAC users as it helps communication partners gain confidence to support the AAC users, leading to improvements in expressive communication and initiation of communication.[66, 67] A systematic review on parent-implemented interventions reported the majority of their studies lacked information on the implementation fidelity during follow-ups.[67] In the current systematic review, only one study[52] reported a high fidelity maintained during a one-month follow-up, making it difficult to conclude whether implementation fidelity is retained once the tele-AAC live coaching is faded. Given its apparent importance, future research is strongly encouraged to explore the implemented fidelity in tele-AAC interventions after the real-time feedback is removed.

Based on the delivered training, the tele-AAC interventions were categorized as Active Consultation[51, 52], FCT[53, 56], teleBCI[54], and a teleintervention compared to an in-person intervention[55]. Due to the small number of participants and the methodological limitations, the results warrant a cautious interpretation. Nonetheless, some important insights may be derived as the included studies offer an in-depth understanding of tele-AAC interventions delivered in a real-life and real-time context.[68]

Active Consultation is the most intensive form of indirect teleservices best suited for novice professionals with limited AAC experience and for communication partners who are new to using and implementing AAC.[69] As a supervisory model, Active Consultation effectively increased the independent use of SGDs, which was also retained during a one-month follow-up.[52] It is worth noting that while the pre-professional[51] reported high satisfaction with the delivery method, this was not the case for the teachers.[52] Teachers reported lower treatment acceptability, likely due to interference with daily routines and barriers to skill maintenance in practical settings. Considering the importance of providing training to novice SLP staff and communication partners in successfully implementing AAC devices, Active Consultation may be the most beneficial coaching method to mitigate any issues with location or personnel shortages while ensuring communication benefits to the AAC user.[51] The number of dyads in these studies is very low and warrants a cautious interpretation of the results. Thus, future research with sufficient statistical power is strongly encouraged to confirm the benefits of Active Consultation as a coaching method in implementing AAC devices.

FCT is a successful evidence-based approach to replacing inappropriate or challenging behavior with an appropriate communicative response.[61] TeleFCT in the included studies[53, 56] were delivered by parents to five non-verbal participants. The main aim was to decrease idiosyncratic behavior and increase independent AAC responses. Overall, teleFCT was successful for all participants in their three individual challenging contexts. This effectiveness is particularly evident in the increased AAC

responses during the return to baseline compared to the first baseline, as well as a continuous increase of AAC responses from one intervention phase to the other. FCT, in general, requires prior assessment of unique, challenging behaviors which guide the intervention. Thus, it seems that teleFCT needs to be implemented on a case-by-case basis, increasing confidence in the reported results of the included studies. A very high implementation fidelity to study procedures was reported in both teleFCT studies, which is also supported by previous research.[70, 71] In addition, teleFCT was highly acceptable as a treatment method by all five parents, thereby providing an overall good treatment option for both the parents and the users.

Combined eye-tracking and BCI devices (i.e., hybrid BCI) are widely used by ALS patients and other patients with severe motor impairments (e.g., locked-in syndrome), allowing them to access computers through brain activity without muscle contribution.[72] Eye-tracking alone seems to be a good option in the early stages of ALS when the eye-gaze fatigue and oculomotor impairments are less severe, whereas, during the late stages of ALS, the BCI is added to facilitate the use of computers for communication.[72] Based on previous research, the most severely disabled people with ALS benefit from the P300-based home systems, which assist communication by producing cued and spontaneous text.[73, 74] As such, teleBCIs[70] may be the best option to offer training to late-stage ALS patients who cannot otherwise interact with a clinical team due to their severe motor limitations.[54] Geronimo and Simmons[54] reported an increase in both accuracy and bit rate per minute once the teleBCI intervention was introduced. In addition, nine of the participants were able to progress from the basic speller to the notepad speller, which allowed them free spelling and production of new words and phrases. Such progress was reported as critical to device usability, which was, in hindsight, associated with increased confidence and capability and perceived benefit of the device.[54] In spite of the overall positive impact on communication, the teleBCI seems to be the most difficult tele-AAC intervention to implement. The study reports numerous technical issues (such as with the electrode cap or the eye-tracking software) that required the coaches to physically visit the participants and facilitate the further continuation of training sessions. This may pose a significant challenge in other contexts when the clinical team cannot assist due to issues like location or personnel shortage. Training the communication partners of the teleBCI users seems to be a plausible solution to mitigate some of these technical issues as they can assist in properly setting up the system for use. This is also supported by the reported increase in confidence in supporting the teleBCI user and decreased burden over time.[54] There is a need for future research in teleBCI to increase more in-depth insights into successfully implementing it, whereas it seems that also, in general, there is a lack of BCI studies with an experimental design when compared to theoretical research, which covers around 70% of BCI literature.[75]

Hall et al.[55] compared the effectiveness of an AAC intervention delivered in-person and through videoconferencing. Results showed a significant increase in independent SGD responses during the tele-AAC intervention compared to the in-person intervention. In addition to its single-case experimental design with weak quality of evidence, the tele-AAC intervention was implemented immediately after the in-person training without any wash-out period. Thereby, the overall effectiveness of the communication training and the comparison between the two delivery methods is impossible to determine. Thus, there is a need for larger-scale future studies to explore the differences between tele-AAC and in-person AAC interventions. Focusing on a context broader than SLP, a recent review[76] on telerehabilitation in children with disabilities reported that teleinterventions

might be as effective as in-person interventions. Similar studies reporting differences between the two delivery methods in SLP are mostly limited to speech-sound disorders.[77, 78] Speech-sound disorders differ from the populations described in the current systematic review, thereby highlighting the need for future research comparing both delivery methods for AAC interventions specifically.

Limitations and directions for future research

The strength of this systematic review is the choice of appropriate tools to assess methodological quality and RoB based on the study design of each study and the thorough search strategy, including both English and non-English literature. Nonetheless, the included studies warrant some critical reflections. The overall quality of evidence is weak to moderate, and the RoB is high. This may stem from the fact that five of the included studies[51-53, 55, 56] had a single-case experimental design which is a rather weak experimental design. Thereby, the results are not representative and generalizable to the specific clinical populations, lacking scientific rigor and increasing the likelihood of biased interpretation of the data.[68, 79] Such is the case with the high RoB in blinding participants, personnel, or outcome assessors which seems to be a methodological issue in most single-case experimental design studies.[49] In addition, studies did not include a control group, preferably one receiving an in-person intervention. This is crucial to establish teleintervention effectiveness as it enables any improvements to be attributed to the intervention itself, thus strengthening the validity and credibility of the findings.[80] Most of the included studies[51, 53-56] lacked a follow-up, which is a significant limitation as it is impossible to judge whether the improvements seen during the intensive training were retained by the AAC users after the real-time feedback was removed. Completeness of follow-up is essential as it determines the validity of study findings and provides valuable information about the long-term benefits of the interventions.[81, 82] Power analysis was not feasible to report for most of the studies (i.e., SCED), thus making it challenging to determine the statistical and clinical relevance of their outcome measures. The only cohort study of this systematic review received the highest possible score in statistical power, based on the inclusion of 14 participants. Downs and Black's checklist[43] gives the highest possible score to studies including more than eight participants, which raises some doubts about whether the checklist is too lenient when scoring statistical power based on sample size. Furthermore, authors[43] do acknowledge that the "power" item had poor reliability (warranting further attention) and is inevitably topic sensitive with regards to the sample size required for a statistically and clinically meaningful result. In general, future studies on tele-AAC interventions with larger sample sizes and more robust methodology are recommended to allow the generalization of results and increased confidence in the benefits of tele-AAC interventions for AAC users with different clinical diagnoses and unique communication needs. Interrater agreement data were not collected and reported in the current systematic review. However, two raters independently judged the inclusion and exclusion of the studies finalized through consensus-building discussions. Inevitably, studies brought together in a systematic review will present some extent of heterogeneity, be it clinical, methodological, or statistical.[83] Given the different clinical diagnoses (disease severity, comorbidities) and age range of the included participants, or timing of outcome measurements, this systematic review may present some clinical heterogeneity.[84] Consequently, to facilitate clinical interpretation, results were reported in a narrative synthesis. Since most of the included studies were single-case experimental design studies with comparable RoB, there appears to be no significant methodological heterogeneity.[84] Similarly, there seems to be no considerable variability in the intervention effects being evaluated (i.e., statistical heterogeneity)[83, 85] as there is consistency in the results of the included studies, that is, studies reported that increased communication competencies were associated with

644 the tele-AAC interventions. Overall, this systematic review followed the good scholarship principles as
645 described in the AMSTAR-2, which gives confidence that the quality of assessment is high, and the
646 included studies were evaluated and reported appropriately.[86]

647 **Conclusions**

648 In spite of several limitations in the methodological quality of the included studies, overall findings
649 suggest that tele-AAC interventions are potentially feasible and effective on a case-to-case basis, given
650 that the majority of the intervention aims were achieved after the training sessions, resulting in overall
651 high satisfaction with the method of the service delivery. This systematic review synthesized insights
652 from four different tele-AAC interventions, namely Active Consultation, FCT, tele-BCI, and tele-AAC
653 compared to in-person intervention. The general aim is to assist the clinical practice with evidence-
654 based knowledge to identify which method of intervention would be more beneficial to each AAC
655 user. To the best of the researchers' knowledge, this is the first review that synthesized the existing
656 evidence on teleinterventions provided directly to the AAC user by researchers and/or clinicians and
657 may thus strengthen the design and methodological quality of future studies in this particular field.

Acknowledgments

The authors have stated that they had no interests which might be perceived as posing a conflict or bias. No funding or financial support was received for writing this systematic review.

Supporting information

S1: Search strategy

S2: Excluded full text journal articles with justification

S3: Quality appraisal of evidence – Downs and Black's checklist

S4: Quality appraisal of evidence – SCED Scale

S5: Risk of bias – ROBINS-I

S6: Risk of bias – SCD RoB

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Mashima PA, Doarn CR. Overview of telehealth activities in speech-language pathology. Telemedicine and e-Health. 2008;14(10):1101-17.
2. Wales D, Skinner L, Hayman M. The Efficacy of Telehealth-Delivered Speech and Language Intervention for Primary School-Age Children: A Systematic Review. International journal of telerehabilitation. 2017;9(1):55-70.
3. Pennington L, Goldbart J, Marshall J. Speech and language therapy to improve the communication skills of children with cerebral palsy. Cochrane database of systematic reviews (Online). 2004(2):CD003466.
4. Tohidast SA, Mansuri B, Bagheri R, Azimi H. Provision of speech-language pathology services for the treatment of speech and language disorders in children during the COVID-19 pandemic: Problems, concerns, and solutions. International Journal of Pediatric Otorhinolaryngology. 2020;138.
5. Nicholas JG, Geers AE. Effects of early auditory experience on the spoken language of deaf children at 3 years of age. Ear and hearing. 2006;27(3):286-98.
6. Organization WH. World report on disability 2011: World Health Organization; 2011.
7. Wylie K, McAllister L, Davidson B, Marshall J. Changing practice: Implications of the World Report on Disability for responding to communication disability in under-served populations. International Journal of Speech-Language Pathology. 2013;15(1):1-13.
8. Cason J, Cohn ER. Telepractice: An Overview and Best Practices. Perspectives on Augmentative & Alternative Communication. 2014;23(1):4-17.
9. Prvu Bettger J, Resnik LJ. Telerehabilitation in the Age of COVID-19: An Opportunity for Learning Health System Research. Physical Therapy. 2020;100(11):1913-6.
10. World Health Organization. Regional Office for the Western P. Implementing telemedicine services during COVID-19 : guiding principles and considerations for a stepwise approach. Manila : WHO Regional Office for the Western Pacific; 2020 2020-11-13. Contract No.: WPR/DSE/2020/032.
11. Association AS-L-H. Telepractice 2013 [Available from: https://www.asha.org/Practice-Portal/Professional-Issues/Telepractice/.
12. Telehealth. American Journal of Occupational Therapy. 2013;67(6_Supplement):S69-S90.
13. Brennan D, Georgeadis A, Baron C. Telerehabilitation tools for the provision of remote speech-language treatment. Top Stroke Rehabil. 2002;8(4):71-8.
14. (WHO) WHO. Telemedicine: Opportunities and developments in Member State. 2010.
15. Keck CS, Doarn CR. Telehealth technology applications in speech-language pathology. Telemed J E Health. 2014;20(7):653-9.
16. Gopalakrishnan S, Ganeshkumar P. Systematic Reviews and Meta-analysis: Understanding the Best Evidence in Primary Healthcare. J Family Med Prim Care. 2013;2(1):9-14.
17. Weidner K, Lowman J. Telepractice for Adult Speech-Language Pathology Services: A Systematic Review. Perspectives of the ASHA Special Interest Groups. 2020;5(1):326-38.
18. Hall N, Boisvert M, Steele R. Telepractice in the assessment and treatment of individuals with aphasia: a systematic review. International journal of telerehabilitation. 2013;5(1):27-38.
19. Repetto C, Paolillo MP, Tuena C, Bellinzona F, Riva G. Innovative technology-based interventions in aphasia rehabilitation: a systematic review. Aphasiology. 2020.
20. Cotelli M, Manenti R, Ferrari C, Gobbi E, Macis A, Cappa SF. Effectiveness of language training and non-invasive brain stimulation on oral and written naming performance in Primary Progressive Aphasia: A meta-analysis and systematic review. Neuroscience and Biobehavioral Reviews. 2020;108:498-525.
21. McGill M, Noureal N, Siegel J. Telepractice Treatment of Stuttering: A Systematic Review. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2019;25(5):359-68.
22. Coleman JJ, Frymark T, Franceschini NM, Theodoros DG. Assessment and Treatment of Cognition and Communication Skills in Adults With Acquired Brain Injury via Telepractice: A Systematic Review. Am J Speech Lang Pathol. 2015;24(2):295-315.

23. Furlong L, Serry T, Bridgman K, Erickson S. An evidence-based synthesis of instructional reading and spelling procedures using telepractice: A rapid review in the context of COVID-19. International Journal of Language & Communication Disorders. 2021;56:456-72.
24. Molini-Avejonas DR, Rondon-Melo S, Amato CA, Samelli AG. A systematic review of the use of telehealth in speech, language and hearing sciences. J Telemed Telecare. 2015;21(7):367-76.
25. Brunner M, Hemsley B, Togher L, Palmer S. Technology and its role in rehabilitation for people with cognitive-communication disability following a traumatic brain injury (TBI). Brain Injury. 2017;31(8):1028-43.
26. Simpson A, El-Refaie A, Stephenson C, Phoebe Chen Y-P, Deng D, Erickson S, et al. Computer-based rehabilitation for developing speech and language in hearing-impaired children: A systematic review. Deafness and Education International. 2015;17(2):111-9.
27. Yuan F, Guo X, Wei X, Xie F, Zheng J, Huang Y, et al. Lee Silverman Voice Treatment for dysarthria in patients with Parkinson's disease: a systematic review and meta-analysis. European Journal of Neurology. 2020;27(10):1957-70.
28. Murray J, Goldbart J. Augmentative and alternative communication: a review of current issues. Paediatrics and Child Health. 2009;19(10):464-8.
29. Light J, McNaughton D. Supporting the communication, language, and literacy development of children with complex communication needs: State of the science and future research priorities. Assistive Technology. 2012;24(1):34-44.
30. Drager K, Light J, McNaughton D. Effects of AAC interventions on communication and language for young children with complex communication needs. Journal of Pediatric Rehabilitation Medicine. 2010;3(4):303-10.
31. Light J, McNaughton D. The changing face of augmentative and alternative communication: past, present, and future challenges. Augmentative and alternative communication (Baltimore, Md : 1985). 2012;28(4):197-204.
32. Creer S, Enderby P, Judge S, John A. Prevalence of people who could benefit from augmentative and alternative communication (AAC) in the UK: determining the need. Int J Lang Commun Disord. 2016;51(6):639-53.
33. Beukelman D, Mirenda P. Augmentative and alternative communication: Supporting children and adults with complex communication needs3rd ed. Paul H Brookes, Baltimore, MD. 2005.
34. National Academies of Sciences E, Medicine. The promise of assistive technology to enhance activity and work participation. 2017.
35. Hong ER, Ganz JB, Neely L, Boles M, Gerow S, Davis JL. A Meta-Analytic Review of Family-Implemented Social and Communication Interventions for Individuals with Developmental Disabilities. Review journal of autism and developmental disorders. 2016;3(2):125-36.
36. Akemoglu Y, Muharib R, Meadan H. A Systematic and Quality Review of Parent-Implemented Language and Communication Interventions Conducted via Telepractice. Journal of Behavioral Education. 2020;29(2):282-316.
37. Law J, Dornstauder M, Charlton J, Gréaux M. Tele-practice for children and young people with communication disabilities: Employing the COM-B model to review the intervention literature and inform guidance for practitioners. International Journal of Language & Communication Disorders. 2021;56(2):415-34.
38. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009;339:b2535.
39. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. Bmj. 2017;358:j4008.
40. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Systematic Reviews. 2016;5(1):210.

41. Jackson JL, Kuriyama A, Anton A, Choi A, Fournier J-P, Geier A-K, et al. The accuracy of google translate for abstracting data from non-English-language trials for systematic reviews. Ann Intern Med. 2019;171(9):677-9.
42. Balk EM, Chung M, Chen ML, Chang LKW, Trikalinos TA. Data extraction from machine-translated versus original language randomized trial reports: a comparative study. Syst Rev. 2013;2(1):97-.
43. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. Journal of Epidemiology and Community Health. 1998;52(6):377.
44. Saunders LD, Soomro GM, Buckingham J, Jamtvedt G, Raina P. Assessing the Methodological Quality of Nonrandomized Intervention Studies. Western Journal of Nursing Research. 2003;25(2):223-37.
45. Hooper PMDF, Jutai JWP, Strong GODM, Russell-Minda EMA. Age-related macular degeneration and low-vision rehabilitation: a systematic review. Can J Ophthalmol. 2008;43(2):180-7.
46. Tate R, McDonald S, Perdices M, Togher L, Schultz R, Savage S. Rating the methodological quality of single-subject designs and N-of-1 trials: Introducing the Single-Case Experimental Design (SCED) Scale. Neuropsychological rehabilitation. 2008;18:385-401.
47. Wendt O, Miller B. Quality Appraisal of Single-Subject Experimental Designs: An Overview and Comparison of Different Appraisal Tools. Education & Treatment of Children. 2012;35(2):235-68.
48. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919.
49. Reichow B, Barton EE, Maggin DM. Development and applications of the single-case design risk of bias tool for evaluating single-case design research study reports. Research in Developmental Disabilities. 2018;79:53-64.
50. Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ. 2020;368:l6890.
51. Boisvert M, Hall N, Andrianopoulos M, Chaclas J. The Multi-faceted Implementation of Telepractice to Service Individuals with Autism. International journal of telerehabilitation. 2012;4(2):11-24.
52. Carnett A, Hansen S, Tullis C, Machalicek W. Using behavioural skills training via telehealth to increase teachers use of communication interventions and increase student use of speech-generating devices in a high school functional skills classroom. J Intellect Disabil Res. 2020.
53. Dimian AF, Elmquist M, Reichle J, Simacek J. Teaching Communicative Responses with a Speech-Generating Device Via Telehealth Coaching. Advances in neurodevelopmental disorders. 2018;2(1):86-99.
54. Geronimo A, Simmons Z. TeleBCI: remote user training, monitoring, and communication with an evoked-potential brain-computer interface. Brain-Computer Interfaces. 2020.
55. Hall N, Boisvert M, Jellison H, Andrianopoulos M. Language Intervention via Text-Based Tele-AAC: A Case Study Comparing On-site and Telepractice Services. Perspectives on Telepractice. 2014;4(2):61-70.
56. Simacek J, Dimian AF, Mccomas JJ. Communication Intervention for Young Children with Severe Neurodevelopmental Disabilities Via Telehealth. Journal of Autism and Developmental Disorders. 2017;47(3):744-67.
57. Sparrow SS. Vineland Adaptive Behavior Scales. In: Kreutzer JS, DeLuca J, Caplan B, editors. Encyclopedia of Clinical Neuropsychology. New York, NY: Springer New York; 2011. p. 2618-21.
58. Sundberg ML, Partington JW. Teaching language to children with autism and other developmental disabilities. Pleasant Hill, CA: Behavior Analysts. 1998.
59. Cedarbaum JM, Stambler N, Malta E, Fuller C, Hilt D, Thurmond B, et al. The ALSFRS-R: a revised ALS functional rating scale that incorporates assessments of respiratory function. Journal of the neurological sciences. 1999;169(1):13-21.

60. Abrahams S, Newton J, Niven E, Foley J, Bak TH. Screening for cognition and behaviour changes in ALS. Amyotroph Lateral Scler Frontotemporal Degener. 2014;15(1-2):9-14.
61. Carr EG, Durand VM. Reducing behavior problems through functional communication training. Journal of applied behavior analysis. 1985;18(2):111-26.
62. Tiger JH, Hanley GP, Bruzek J. Functional communication training: A review and practical guide. Behavior analysis in practice. 2008;1(1):16-23.
63. Reimers TM, Wacker DP. Parents' Ratings of the Acceptability of Behavioral Treatment Recommendations Made in an Outpatient Clinic: A Preliminary Analysis of the Influence of Treatment Effectiveness. Behavioral Disorders. 1988;14(1):7-15.
64. Scherer MJ, Craddock G. Matching Person & Technology (MPT) assessment process. Technology and Disability. 2002;14:125-31.
65. Goossens C. Aided communication intervention before assessment: A case study of a child with cerebral palsy. AAC: Augmentative and Alternative Communication. 1989;5(1):14-26.
66. Farzana W, Sarker F, Vaidyanathan R, Chau T, Mamun KA, editors. Communication Support Utilizing AAC for Verbally Challenged Children in Developing Countries During COVID-19 Pandemic2020; Cham: Springer International Publishing.
67. Barton EE, Fettig A. Parent-Implemented Interventions for Young Children With Disabilities: A Review of Fidelity Features. Journal of Early Intervention. 2013;35(2):194-219.
68. Crowe S, Cresswell K, Robertson A, Huby G, Avery A, Sheikh A. The case study approach. BMC medical research methodology. 2011;11:100-.
69. Hall N, Boisvert M. Clinical Aspects Related to Tele-AAC: A Technical Report. Perspectives on Augmentative & Alternative Communication. 2014;23(1):18-33.
70. Suess AN, Romani PW, Wacker DP, Dyson SM, Kuhle JL, Lee JF, et al. Evaluating the Treatment Fidelity of Parents Who Conduct In-Home Functional Communication Training with Coaching via Telehealth. Journal of Behavioral Education. 2014;23(1):34-59.
71. Neely L, Rispoli M, Gerow S, Hong ER, Hagan-Burke S. Fidelity Outcomes for Autism-Focused Interventionists Coached via Telepractice: a Systematic Literature Review. Journal of Developmental and Physical Disabilities. 2017;29(6):849-74.
72. Pinto S, Quintarelli S, Silani V. New technologies and Amyotrophic Lateral Sclerosis – Which step forward rushed by the COVID-19 pandemic? J Neurol Sci. 2020;418.
73. Nijboer F, Sellers EW, Mellinger J, Jordan MA, Matuz T, Furdea A, et al. A P300-based brain–computer interface for people with amyotrophic lateral sclerosis. Clinical Neurophysiology. 2008;119(8):1909-16.
74. McCane LM, Sellers EW, McFarland DJ, Mak JN, Carmack CS, Zeitlin D, et al. Brain-computer interface (BCI) evaluation in people with amyotrophic lateral sclerosis. Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration. 2014;15(3-4):207-15.
75. Bamdad M, Zarshenas H, Auais MA. Application of BCI systems in neurorehabilitation: a scoping review. Disability and rehabilitation Assistive technology. 2015;10(5):355-64.
76. Camden C, Pratte G, Fallon F, Couture M, Berbari J, Tousignant M. Diversity of practices in telerehabilitation for children with disabilities and effective intervention characteristics: results from a systematic review. Disability and Rehabilitation. 2020;42(24):3424-36.
77. Bernie E, editor Critical Review: What is the efficacy of a telepractice service delivery model when compared to traditional on-site therapy for school-aged children receiving speech sound intervention (SSI)?2019.
78. Coufal K, Parham D, Jakubowitz M, Howell C, Reyes J. Comparing traditional service delivery and telepractice for speech sound production using a functional outcome measure. American Journal of Speech-Language Pathology. 2018;27(1):82-90.
79. Zainal Z. Case study as a research method. Jurnal Kemanusiaan. 2007;9.
80. Kinser PA, Robins JL. Control group design: enhancing rigor in research of mind-body therapies for depression. Evid Based Complement Alternat Med. 2013;2013:140467-.

81. Llewellyn-Bennett R, Bowman L, Bulbulia R. Post-trial follow-up methodology in large randomized controlled trials: a systematic review protocol. Systematic Reviews. 2016;5(1):214.
82. von Allmen RS, Weiss S, Tevaearai HT, Kuemmerli C, Tinner C, Carrel TP, et al. Completeness of Follow-Up Determines Validity of Study Findings: Results of a Prospective Repeated Measures Cohort Study. PloS one. 2015;10(10):e0140817-e.
83. Higgins JPT, Thomas J. Cochrane Handbook for Systematic Reviews of Interventions. Second Edition ed: Oxford : Wiley Blackwell; 2019.
84. Gagnier JJ, Morgenstern H, Altman DG, Berlin J, Chang S, McCulloch P, et al. Consensus-based recommendations for investigating clinical heterogeneity in systematic reviews. BMC Medical Research Methodology. 2013;13(1):106.
85. Higgins J, Thompson S, Deeks J, Altman D. Statistical heterogeneity in systematic reviews of clinical trials: a critical appraisal of guidelines and practice. J Health Serv Res Policy. 2002;7(1):51-61.
86. Kolaski K, Romeiser Logan L, Goss KD, Butler C. Quality appraisal of systematic reviews of interventions for children with cerebral palsy reveals critically low confidence. Developmental medicine and child neurology. 2021.

Table 1. Summary of studies – participant characteristics

Study	Participant characteristics					
	Sample size	**Diagnosis**	**Sex (m:f)**	**Age (years or mean±SD)**	**Functional profile assessment**	**AAC technology**
Boisvert et al., 2012	n=1	ASD	1:0	11	Significant expressive language deficits	iPad with a voice output application which converted it into SGD
Carnett et al., 2020	n=4	Mitochondrial myopathy (n=1), ASD (n=1), Down syndrome (n=2)	3:1	15, 18, 20, 22	VABS; BLAF	iPad equipped with the speech synthesizing software GOTALK NOW Tobii Dynavox I-12 eye tracker
Dimian et al., 2018	n=2	ASD (n=1); Developmental delay (n=1)	2:0	5.5, 7	FAI; VABS; SDA; FAI	Tobias Dynavox T10 touch-screen with Tobii Dynavox Compass Software
Geronimo and Simmons., 2020	n=14	ALS (n=12); PLS (n=1); PMA (n=1)	10:4	63.7 ±8.2	ECAS; ALSFRS-R	P300 Speller with 2 online spelling systems
Hall et al., 2014	n=1	Schizencephaly	1:0	7	Significant expressive language deficits	Vantage Plus AAC device
Simacek et al., 2017	n=3	ASD (n=2); Rett syndrome (n=1)	0:3	3.5, 3.5, 4	FAI; VABS; SDA; FAI	Go Talk SGD ASL signs 2D picture cards Bigmack micro-switch with voice output

ASD, Autism Spectrum Disorder; ALS, Amyotrophic Lateral Sclerosis; PLS, Primary Lateral Sclerosis; PMA, Progressive Muscular Atrophy; AAC, Augmentative and Alternative Communication; SGD, speech-generating device; ASL, American Sign Language; SD, standard deviation; VABS, Vineland Adaptive Behavior Scale - semi-structured interview to measure adaptive behavior and support the diagnosis of intellectual and developmental disabilities, autism, and developmental delays; BALF, Behavioral Language Assessment Form - determines where to start a language intervention program based on person's skills; FAI, Functional Assessment Interview – used to gather information in a structured manner; SDA, Structured Descriptive Assessment - uses principles of applied behavior analysis to describe the causes and consequences of a given behavior; FA, Functional Assessment - observing and analyzing behaviors within naturally occurring everyday routines and activities across multiple situations and settings; ECAS, Edinburgh Cognitive and Behavioral ALS Screen - to assess cognitive and behavioral changes common in patients with ALS; ALSFRS-R; ALS Functional Rating Scale – Revised - to establish baseline severity at diagnosis and to assess disease progression over time

888

Table 2. Summary of studies – study characteristics

Study	Study characteristics									
	Design	**Baseline**	**Intervention**	**Follow-up**	**Duration of study**	**Interventionist**	**Place of intervention**	**Teleintervention technology**	**Outcome measure**	**Reported funding**
Boisvert et al., 2012	Single-case experimental design	Video observation, no SGD used	Active Consultation Production of phrases and varied phrases	N/A	10 weeks, 1 session per week; 60 min/day (2A+8B)	Senior- and pre-professional	University room	Marchal 8.4" high-resolution LCD monitor; Bluetooth headset connected to a cellular phone; Sony Cybershot camcorder with a built-in microphone	Frequency count of produced phrases and varied phrases Satisfaction with the Active Consultation using a Likert-scale survey	U.S. Department of Education, Office of Special Education and Rehabilitative Services (CFDA 84.325D, H325D080042)
Carnett et al., 2020	Single-case experimental design	10-minute recording and observation	Active Consultation SGD picture symbols of preferred and non-preferred items	1-month follow-up	CS1=32 sessions (5A+12B+5A+7B+3C) CS2=30 sessions (5B+6A+8B+5A+3B+3C) CS3=27 sessions (5A+8B+5A+6B+3C) CS4=31 sessions (11B+5A+8B+6D)	Telecoaches Teachers	Classroom	Laptop or iPad; Jabra Stealth Bluetooth Headset; SCREEN CAST-O-MATIC session recorder Videoconferencing platform: VSEE	Frequency of independent activation of SGD by (1) pressing the symbol that activates the synthesized speech and (2) activation of the SGD within a predefined context (i.e., corresponding to a specific item) Teacher fidelity to communication teleinterventions Interobserver agreement calculated for	No external funding

									40% of baseline data and 30-33% of intervention data TARF-R – a 20-item rating scale adapted to include telehealth components evaluating treatment acceptability	
Dimian et al., 2018	Single-case experimental design	3-minute recording to identify tantrums, idiosyncratic behavior, spoken word comprehension	FCT to teach functionally equivalent replacement behavior in the form of AAC Navigation between a superordinate and a subordinate page set	N/A	CS1=7 weeks, 142 3-min sessions (2-3x a week, 30min/day) CS2=23 weeks, 89 5-trial block sessions (3x a week, 30min/day)	Telecoaches Parents	Participant's home	Dell OPtiPlex 3010 Desktop computer with a Dell 24" monitor and a Logitech HD ProWebcam C920; Polaroid 8″ Heavy Duty Mini Tripod, Logitech ClearChatComfort/USB Headset H390; Debut screen-recording software Video conferencing platform: Google Hangout	Frequency of AAC symbol production (i.e., accurate activation of a symbol that produced a voice output message during three meaningful contexts identified per participant) compared to idiosyncratic behaviour (i.e., reaching, pointing, tantrum). Procedural fidelity to communication teleinterventions	Grant T73MC12835–03-00 from the Maternal & Child Health Bureau (MCHB) of the US Department of Health and Human Services

									Interobserver agreement calculated for 35-40% of all sessions TARF-R – rating scale to evaluate treatment acceptability	
Geronimo and Simmons., 2020	Cohort study	Initial session, home visit to assess visual evoked responses	Progress from training program to notepad speller	N/A	9 sessions, 60-90min/day N=1 baseline/home visit N=8 teleBCI sessions	Telecoaches Communication partners	Participant's home	Windows 10-based laptop with integrated mic and webcam A second patient-facing monitor with a mounted Tobii eyeFx eye-tracking bar; 8-channel g.Nautilus cap with gelled Scarabeo electrodes; Videoconferencing platform: Adobe Connect	Communication accuracy and effective bit rate ATDPA – rates the functionality of the device to user's communication needs in 12 domains, rated on 1-5 scale, with a total score of 60 indicating maximum expected benefit.	ALS Association Clinical Management grant 17-CM-325; Grants UL1TR000127 and UL1TR002014
Hall et al., 2014	Single-case experimental design	Frequency of generating and using morphemes *ing, ed, plural-s*	Grammatical morpheme intervention	N/A	12 sessions, 60min/day (4A+4Ba+4Bb)	Telecoach Parent	Participant's home	Hewlett-Packard (HP) TouchSmart tx2 and Dell Pavillion dv6 computer; Videoconferencing platform: Skype	(1) Frequency of generating three grammatical morphemes ing, *ed, plural-s* and (2) frequency of each morpheme's use	U.S. Department of Education Office of Special Education Programs (H325D080042).

									Method of service delivery (in-person and telepractice) using Tau-U statistics	
Simacek et al., 2017	Single-case experimental design	Occurrence of idiosyncratic responses, AAC present but no prompts to use it	FCT to teach functionally equivalent replacement behavior in the form of AAC	N/A	7 sessions; 30 min/day across three contexts CS1=37 5-min sessions per context; 16 days CS2=126 3-trial block sessions per context; 18 days CS3=37 5-min sessions per context; 16 days	Telecoaches Parents	Participant's home	Dell OptiPlex 3010 Desktop with Dell 24" monitor, Logitech HD Pro Webcam C920; Logitech ClearChat Comfort/USB Headset H390; Polaroid 8″ Heavy Duty Mini Tripod Videoconferencing platform: Google Hangout	Frequency of AAC symbol production (i.e., accurate activation of a symbol that produced a voice output message during three meaningful contexts identified per participant) compared to idiosyncratic behaviour (i.e., reaching, clapping, tantrum). Procedural fidelity to the communication teleinterventions Interobserver agreement calculated for 25-30% of randomly selected sessions TARF-R – a 21-item rating	NIH/NICHD, Grant No. 44763

									scale to measure parent's perception of acceptability and parent's perception of the severity of the problem; modified to include the term "communicatio n"	

A, baseline; B, intervention, C, follow-up, D, procedural modifications; Ba, intervention in-person; Bb, teleintervention; FCT, Functional Communication Training; BCI, Brain-Computer Interface; N/A, not applicable; min/day, minutes per day; TARF-R, Treatment Acceptability Rating Form-Revised; ATDPA, Assistive Technology Device Predisposition Assessment

889

Table 3. Outcome measures and results

Study	Outcome		Baseline (A) Mean (SD) [range]		Intervention (B) Mean (SD) [range]				Conclusion
Boisvert et al., 2012	Use of SGD		**Pre-professional**	**User**	**Pre-professional**		**User**		A significant trend of improvement in frequency count of the produced number of phrases and varied phrases by both the pre-professional and the SGD user
		Nr of phrases	0	0	42.3 (20.5) [19-85] C-index=0.541; p=0.039		73.4 (24.9) [44-105] C-index=0.513; p=0.048		
		Nr varied phrases	0	0	9.1 (4.6) [2-15] C-index=0.547; p=0.038		21.0 (13.5) [2-41] C-index=0.620; p=0.022		
	Satisfaction survey		/	/	4.8 (0.1) [4.6-4.9]		/		Very high satisfaction with AC as a delivery method
Carnett et al., 2020	Teacher fidelity % (CS1; CS2; CS3; CS4)		**1A**	**2A**	**1B**	**2B**	**3B**	**Follow-up**	An increase in teacher fidelity is seen during intervention phases and a decrease during the baselines. Fidelity is kept similar to the intervention during follow-up
			24 [20-30]; 22 [10-30]; 14 [10-20]; 20 [20-20];	58 [50-60]; 24 [10-40]; 46 [40-50]; /	90 [80-100]; 90 [50-90]; 89 [80-100]; 85 [70-100];	94 [90-100]; 97.5 [90-100]; 88 [80-100]; 82 [70-90];	/ 97 [90-100]; / 93 [90-100];	97 [90-100]; 87 [80-90]; 97 [90-100]; /	
	Student SGD use	Independent mands (%)	0; 0; 0; 0;	12 [0-33]; 0; 6 [0-10]; /	71 [17-100]; 93 [79-100]; 71 [0-100]; 52 [22-85];	83.5 [55-100]; 74 [20-98]; 96 [85-100]; 43 [0-90];	/ 94 [88-98]; / 100; 27 [0-90]*	96 [88-100]; 88 [80-100]; 97 [90-100]; /	An increase in independent mands and frequency of mands with SGD is seen in all users during the intervention phases with retained results during follow-up *, CS4 results were reported as 100% with a "look prompt" and as 27% without the "look prompt".
		Frequency of mands (nr)	1.8 [1-2]; 3 [0-5]; 5 [4-6]; 13 [10-18];	2 [0-4]; 1 [0-3]; 15 [10-20]; /	6.9 [4-10]; 28 [14-42]; 12 [9-15]; 14 [7-26];	7.6 [5-13]; 26 [19-35]; 13 [11-15]; 10 [4-21];	/ 25 [19-30]; / 13 [2-28];	6 [5-7]; 25 [22-28]; 11 [10-12]; /	
	IOA (CS1%; CS2%; CS3; CS4%)		100% for each CS		93.5, 97.0, 92.4, 98.0			/	High IOA
	TARF-R		4.86; 4.32 [2-5]; 3.5 [3-4]; 4.0 [2-5];		3.94 [3-5]; 3.88 [3-5]; 4.05 [2-5]; 3.82 [2-5];			/	Possible that the intervention interfered with daily routines, indicating a barrier to skill maintenance in practical settings
Dimian et al, 2018	CS1		**1A**	**2A**	**1B**	**2B**	**2B***	**2B****	
	Play	Idiosyncratic %	22 [5-45]	18 [15-25]	5 [0-10]	3.5 [0-10]	/	/	Overall, an increase in independent AAC responses with decreased
		AAC %	0	4 [0-5]	19 [15-25]	15 [10-25]	/	/	
	Break	Idiosyncratic %	56 [0-90]	/	13 [0-60]	/	/	/	

			AAC %	0	/	12 [0-30]	/	/	/	idiosyncratic behavior is seen once the FCT is introduced. Modifications to the FCT that facilitate the abilities of the participant (2B* and 2B**) may be necessary to ensure higher efficiency of training.
		Help	Idiosyncratic %	11 [0-30]	/	0	/	/	/	
			AAC %	0.6 [0-10]	/	15 [10-25]	/	/	/	
	CS2	Play	AAC complete%	24 [0-40]	49 [20-80]	12 [0-40]	63 [40-100]	80 [60-100]	91 [80-100]	
		Help	AAC complete%	5 [0-20]	/	57 [0-100]	/	/	/	
		Break	AAC complete%	9 [0-40]	/	61 [0-100]	/	/	/	
	IOA (CS1%; CS2%)			98 [77-100] 98 [80-100]		98 [79-100] 97 [80-100]				Very high IOA
	TARF-R			/		Highly acceptable				High treatment acceptability
	Procedural fidelity (CS1%; CS2%)			92 [78-100] 96 [67-100]						High fidelity
Geronimo and Simmons., 2020	TeleBCI communication		Accuracy %	**A** **Median [IQR1-IQR3]** 34 [8-70]		**B** **Median [IQR1-IQR3]** S1=50 [32-66] S2=60 [45-65] S3=55 [45-65] S4=60 [15-70]		S5=55 [40-88] S6=63 [35-75] S7=45 [28-68] S8=60 [37-88]		The communication accuracy showed an increase of 22% on average from baseline to intervention and an increase of 2.8 bits per minute.
			Bit rate per minute	6 [0.2-12.5]		S1=6.5 [4-9.5] S2=11 [6-11.5] S3=9.5 [6-13.5] S4=8 [1-12]		S5=9 [5-16] S6=10 [4.5-16] S7=7 [4-12.5] S8=9 [6-14]		
	Trainer (n of participants; S1-S8)			14		14; 14; 13; 13; 13; 13; 12; 12				Nine participants progressed to using the notepad speller during at least one intervention session.
	Notepad (n of participants; S1-S8)			2		3; 5; 8; 6; 8; 7; 8; 9				
			Text-to-Speech	1		1; 1; 5; 2; 5; 3; 4; 6				
			Text prediction	1		2; 3; 6; 5; 4; 4; 5; 6				
			Prepared text	0		1; 2; 4; 3; 4; 3; 4; 5				
	ATDPA			/		First visit 44.1%; Last visit 38.9%				The major improvement was reported in confidence to use the teleBCI, whereas the major decrease was associated with device burden (BCI fitting into a routine, having the stamina to use, having the required support, and fitting in the home).
Hall et al., 2014				**A** **Mean (SD) [range]**		**1B (in-person)** **Mean (SD) [range]**		**2B (teleintervention)** **Mean (SD) [range]**		Accuracy increased significantly during the intervention compared to

	Use of *ed, ing, -s* morphemes		Probe accuracy%	3 [0-10]		79 [30-100]	100	the baseline, with a significant increase of independent responses during the teleintervention compared to the in-person training.
			Prompted responses %	0		52 [18-80]	5 [0-20]	
			Independent responses %	0		48 [20-82]	95 [80-100]	
	Tau-U statistics			A vs 1B p<0.05; A vs 2B p<0.05; 1B vs 2B p=0.25; 1B independent responses vs 2B independent responses p<0.05				
				1A	**2A**	**1B**	**1B¥**	**2B**
Simacek et al., 2017	CS1	Snack/Drink	Idiosyncratic %	27 [25-30]	39 [13-63]	15 [0-75]	/	0
			AAC %	1 [0-5]	43 [13-88]	34 [8-100]	/	55 [25-75]
		Video	Idiosyncratic %	43 [35-88]	/	3 [0-25]	/	/
			AAC %	3 [0-13]	/	59 [0-88]	/	/
		Break	Idiosyncratic %	31 [0-50]	/	10 [0-50]	/	/
			AAC %	0	/	39 [25-75]	/	/
	CS2	Food/Drink	Idiosyncratic %	77 [65-100]	50 [0-100]	45 [0-100]	7 [0-65]	25 [0-65]
			AAC %	12 [0-35]	34 [0-100]	50 [0-100]	98 [35-100]	73 [0-100]
		Toy	Idiosyncratic %	92 [65-100]	/	17 [0-65]	/	/
			AAC %	19 [0-35]	/	87 [0-100]	/	/
		All done	Idiosyncratic %	100	/	31 [0-100]	/	/
			AAC %	12 [0-35]	/	52 [0-100]	/	/
	CS3	Food	Idiosyncratic %	38 [27-50]	30 [17-40]	8 [0-27]	/	8 [0-17]
			AAC %	18 [2-33]	18 [3-30]	70 [53-100]	/	37 [27-57]
		Snack	Idiosyncratic %	44 [33-60]	/	4 [0-13]	/	/
			AAC %	0	/	33 [17-50]	/	/
		Atten-tion	Idiosyncratic %	31 [3-50]	/	4 [0-13]	/	/
			AAC %	1 [0-7]	/	19 [7-33]	/	/
	IOA % (CS1, CS2, CS3)		Idiosyncratic	91 [78-100]; 89 [67-100]; 94 [85-100]				Very high IOA
			AAC	93 [84-100]; 91 [67-100]; 97 [92-100]				
	Procedural fidelity % (CS1, CS2, CS3)			96 [83-100]; 93 [71-100]; 94 [83-100]				High fidelity
	TARF-R			Highly acceptable				High treatment acceptability

A, baseline; B, intervention; SGD, speech-generating device; AAC, augmentative and alternative communication; IOA, interobserver agreement; BCI, Brain-Computer Interface; TARF-R, Treatment Acceptability Rating Form-Revised; ATDPA, Assistive Technology Device Predisposition Assessment; FCT, Functional Communication Training; 2B*, Functional Communication Training with superordinate symbols on the navigation bar; 2B**, Functional Communication Training with superordinate symbols in an array; 1B¥, Functional Communication Training intervention + time delay;

Figure legends

Figure 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram detailing the database search process and the different review stages