



Assistive learning technologies for learners with ADHD and ASD

– a review 2006-2016

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Abstract

This literature review was a part of a research project investigating how technologies can be utilised to support learners with developmental and attention deficit to be included in mainstream learning contexts. The review contains research within the field of assistive learning technologies for learners with Attention Deficit Hyperactivity Disorder and Autism Spectrum Disorder from 2006 to 2016. The review is conducted, by using systematic and qualitative academically acknowledged literature search methods. Seven categories of technology-based interventions are recognised from current research, where technologies have been used to support: 1) memory disabilities and/or brain training, 2) increasing focusing attention, 3) time and task management, 4) communication, 5) reading, writing, language and literacy skills, 6) changing behaviour and 7) group work and collaboration. The results indicate that the overall findings of the rendered studies present mixed conclusions. The review calls for more research in a mainstream learning context with a universal design for learning approach.

Keywords: *Assistive Technologies, ADHD, ASD, Learning, Technology-based interventions*

1. Introduction

The aim of this review was to examine how assistive technologies can be utilised to support learners with developmental and attention deficits to participate and contribute in learning activities in mainstream learning contexts.

'*Learners with developmental and attention deficits*' is an imprecisely umbrella term of an inhomogeneous group of children challenged in life and learning, but in many studies defined collectively under this concept (Danmarks Evalueringsinstitut, 2011; Søggaard et al., 2013; Dyssegaard et al., 2013a). Children with Special Educational Needs (SEN) are defined as children, which break with age appropriate current rules, norms and expectations when compared to children in the basic school with a regular character over time (Nordahl et al., 2009; Søggaard et al., 2013).

The delimitation in this paper is formed primarily by the diagnosis Attention Deficit Hyperactivity Disorder (ADHD) and secondary by Autism Spectrum Disorder (ASD), yet these diagnoses include many variations of challenges and associated comorbid disorders as e.g. learning difficulties, socio-emotional and environmental determined difficulties, mental disorders, reading and writing difficulties, speech and language difficulties. (Danmarks Evalueringsinstitut, 2011).

It is a difficult endeavour to search for academic literature in this field because concepts and definitions vary across different professions or geographic areas. McKnight and Davies (2012) emphasises furthermore, that varying concepts make it difficult to search precisely and efficient on exact groups:

“ People looking for information on technology for users with Asperger’s syndrome may find sources on Asperger’s, autism, autistic spectrum disorders (ASD), or they may be classed as behavioral or communication disorders.”

(McKnight and Davies, 2012)

Attention Deficit Hyperactivity Disorder

ADHD is characterised by the core symptoms of attention difficulties and/or impulsivity, but the symptoms appears in different combinations (Wilens et al., 2002). The prevalence is varying, but consensus on 4-10 % in childhood and 4-5 % in adulthood seems evident (Almer and Sneum, 2009).

Attention deficit is recognised when a child is unable to stay concentrated, often distracted by external stimulus, not seems to listen when directly addressed, and needs to have instructions and explanations numerous times. The hyperactivity and impulsivity manifest itself both physically and verbally, when a child is fidgeting agitated with things, moving restlessly on the chair or toddling with one’s feet, talking excessively, finds it difficult to wait and continuously interrupts people’s speech or play (Almer and Sneum). The symptoms of ADHD are sensitive to situation and context; a child with ADHD can be calm, immersed and attentive in some situations and interrupting, fidgety and unattended in another situation (Barkley, 2006). The demands and level of cognitive complexity seems to play a significant role.

The comorbidity of ADHD and psychiatric disorders or learning disabilities are another factor that draw a complex picture of the issues and hinder a clear delimitation and definition of the diagnosis. To some extent are all psychiatric conditions are represented, but the most occurring are learning difficulties (LD), behaviour disorder, one or more criteria from the autistic spectrum, bipolar affective disorder, tics or Tourette Syndrome, and anxiety disorder (Almer and Sneum, 2009).

Children with ADHD are challenged in life and learning: low productivity and poor organisation abilities (DuPaul and Stoner, 2003), weaknesses in attention (Mayes and Calhoun, 2007), memory problems (Alloway et al., 2010), narrative competence (Rumpf et al., 2012), dyslexia (Germanò et al., 2010), social deficits in play (Docking et al., 2013), poor self-regulation (Healey and Halperin, 2015). It seems relevant to examine if technologies can support individuals with ADHD with respect to some of these challenges when participating in learning activities.

Autism Spectrum Disorders

ASD has since May 2013 been an umbrella term for all earlier autism disorders including autistic disorder, childhood disintegrative disorder, pervasive developmental disorder-not otherwise specified, and Asperger syndrome (American Psychiatric Association, 2013). The term spectrum illustrates that there are many types of autism in this lifelong pervasive social disability. ASD affects one in 166 children and apparently there is no cure. The diversity of combinations is extensive from low functioning, infantile autistics with none or very little language and intelligence, to high functioning autistics with normal to high intelligence.

Individuals with ASD are characterised by persistent deficits in social communication and social interaction across contexts, and restricted, repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). Symptoms are typically identified in early childhood but might not become fully manifested before social demands exceed the limited capacities. They could as well be masked by sufficient learning strategies later in life (American Psychiatric Association, 2013). Following this perspective, it seems relevant to investigate how assistive technologies can be used to support learners with ASD in learning activities

Assistive technologies

Overall, there is promise of technologies for supporting learning in SEN settings (McKnight and Davies, 2012). Although a large amount of research is available in this field, much of it must be considered as exploratory work or prototype tests of possible benefits of emerging tools (Ploog et al., 2013a). The literature on using assistive technologies in real world practice is very limited (Abbott, 2007a; Abbott et al., 2011).

Definitions of Assistive Technologies (AT) vary and are even sometimes contradicting (Abbott, 2007b). Abbott et al. (2011) defines AT as a complex phenomenon that takes place in real life, involving technologies, humans and activities in different contexts at three taxonomic levels:

- Technologies to train and rehearse
- Technologies to assist learning
- Technologies to enable learning

Technologies for training and rehearsing are very common. They are often built on a behaviouristically model of learning with a good income stream for developers, but offering limited educational validity (Abbott, 2007b). The pervasiveness of iPads in such situations has increased the amount of related applications commercially available.

Today, technologies to assist learning are exponentially increasing and include voice recognition, text-to-speech or speech-to-text functionalities

implemented in mainstream, generic technologies. They can be used to compensate disabilities and move towards more equality with other learners.

Depending on the users' specific challenges the same technologies as mentioned above may in some situations, not only assist learning, but also allow learning to take place. The intersection of technology, user and practice leads to a learning gain (Abbott, 2007b).

It can be difficult for educators and caregivers to optimally adapt assistive technologies to a specific user. Promising recommendations on the technology itself are recognised, but how will they fit users with such a diverse set of challenges as individuals with ASD and ADHD? McKnight and Davies (2012) suggests it might be better for educators or caregivers to think on all individuals as having differences rather than some have disabilities. In their review they suggest large multi-touch surfaces, tangible technologies, and tools for scheduling and organising as valuable tools for learners with ASD. While technologies for keep focussing on task, rehearse appropriate behaviour and support collaboration are recommended for learners with ADHD.

Farr (2010) emphasizes that personalised technologies have been shown to work best for individuals with ASD, and point at blogs and video blogs as new and promising fields, where

“Autistic users are sharing information and joining debates... For the first time, individuals on the autistic spectrum have a voice in the debate and are able to express their view about what they like.”

(Farr, 2010)

It is evident that the use of technologies is both acceptable and motivating for our focus group of learners. This is in line with Lindstedt and Umb-Carlsson, 2013; Parker and Banerjee, 2007. The literature also indicated how evidence for improved learning outcome is more flawed (Ploog et al., 2013b). This statement might lead us to a scientific theoretical discussion on what is measurable. But instead of such a detour the authors of this review posit that increased motivation, engagement, participation and contribution increases the possibilities for learning to occur. With this position this review examines how technologies can be utilised to support learners with attention and developmental deficits to participate and contribute in learning activities.

The chapter 2 clarifies the search methods behind the review followed by a brief description of the relevance of the selected research articles in the chapter 3. The chapter 4 presents the findings on relevant assistive technologies for learners with ADHD and ASD, while chapter 5 establishes a forum for discussion and conclusions and bring in perspectives aligned to further investigations.

2. Search methods

We have used two methods for the literature search: 1) a systematic Internet search with broad terms used on academic online literature databases, and 2) a walk-through of references in central publications combined with additional Internet searches. The latter is known as snowballing (Wohlin, 2014), which is a search approach for additional literature studies. Snowballing is achieved by rendering the reference list of papers or the citations to the paper to identify additional relevant papers.

The literature search focuses on a time span from 2006 to 2016. The overall methodology for handling the search results is aligned with PRISMA's approach to literature reviews (Moher et al., 2009). The method has its roots in the research field of medicine and presents a well-structured flow diagram and a checklist for conducting systematic reviews in all fields of research. Especially the four-phased flow diagram (identification, screening, eligibility and including) supports the authors of this review in finding all literature that are related to assistive learning technologies for learners with ADHD and/or ASD.

2.1 Systematic Internet search

The following terms are selected as central to the field and broad enough to capture published research: *'ADHD'*, *'Technology'*, *'Learning'* and *'Primary School'*. These terms are applied in a search for Danish literature on the online *'Danish National Research Database'* with following results (table 1):

Table 1 Systematic internet search – Danish context

Date 13th of april 2016	Search terms	Results	Result-categories			
Online database		Total	Researchpapers	PhD	Reports	Teaching manuals
Forskningsdatabasen	"ADHD", "Læring"	3		1	1	1
	"ADHD", "Teknologi"	1	1			
	"ADHD", "folkeskole"	1	1			

The search in a Danish rooted context generates only few articles, and since these are not focussing specifically on our focus group and technologies the results are excluded. This indicates that research in this field in a Danish context does not exist.

Another search for literature in an anglophone context is structured by following search terms: *'Technology'* and *'Children with ADHD'* on three online databases: *Scopus*, *Web of Science* and *Google Scholar*.

Table 2 Systematic internet search – international context

Online database	Date	Search terms	Total searchresults	Number of the relevant outcome
Scopus	19-02-2016	"Technology", "Children with ADHD"	29	13
Web of Science	20-02-2016	"Technology", "Children with ADHD"	65	9
Google Scholar	22-02-2016	"Technology", "Children with ADHD"	950	16

These searches prompt at first respectively 29, 65 and 950 articles from 2006-2016 as shown in table 2. The search results are subsequently classified to each research area. There is an evident overweight of publications regarding to medication or physiological studies on ADHD and brain activities. These publications have no relevance for this review, which is why they are excluded by the segregation mechanisms at the databases. The results are then scrutinised qualitatively in preparation for exclusion of publications beside the point to focus the review. After this critical examination, the results for the systematic internet search resulted in 17 relevant articles.

2.2 Additional snowballing search methods

As mentioned earlier in this contribution, it is difficult to accomplish a search for academic literature in this field. The authors know about literature, that did not appear through the systematic internet search described above. Given our need for more knowledge on this field than the 17 articles found, an additional 'handheld' snowball search method is used (Wohlin, 2014).

First, the references in the seventeen articles and some major review as e.g. McKnight and Davies (2012), are examined. Additional searches at the University Library Search Engine resulted as shown in table 3:

Table 3 Search terms

Search terms in the period; 2006-2016	Hits
Autism Spectrum AND Learning Technologies AND Children	267
ADHD AND Learning Technologies AND Children	96
ADHD AND Learning AND Collaboration	66
ADHD AND Learning AND Dialogue	14
Total	443

Rendering abstracts excludes the main part of these articles caused to their relation to medical or psychiatric treatment rather than education and learning. The limits between education and treatment can be fluid in certain educational settings. Summing up, the additional snowball search contributes with 52 two articles (n= 52).

3. Data

During both search methods, in total 69 articles were identified. Only half of them are specifically addressing assistive learning technologies and ADHD/ASD as shown in table 4.

Table 4 Overall themes in articles

Overall theme of articles	Number of articles
General knowledge on AT	8
General knowledge on ADHD	11
General knowledge on ASD	4
Other important issues	10
Technology for the target group	36
Total	69

Table 5 shows, how one third of the articles are reviews or researcher comments/discussions, while two third are novel research studies. Caused the amount of comorbid conditions to both diagnoses 14 general articles on AT are included.

Table 5 Research categorisation

Research categorisation	ADHD	ASD	AT	Total
Research review	8	4	4	16
Research discussion	1	2	2	5
Research study	20 + 5* = 25	15 + 5* = 20	8	48 (53*)
Total	34	26	14	69

* Five research studies are on both ADHD and ASD

A closer look at the 48 articles in table 6 shows only 21 studies related specific to educational contexts, while 27 studies are laboratory tests, treatment studies, development of tools related to everyday life functioning outside the school or interviews/surveys on different conditions in school and life.

Table 6 Field of research

Research direction	ADHD	ASD	AT	Total
Labratorial	7	6		13
Education	8 – 2 SEN/6 MAIN	6 - 3 SEN/3 MAIN	7 – 1 SEN/6 MAIN	21
Treatment	4	3	1	8
Development	3	2		5
Everyday Life	1	1		2
Survey	2	2		4
Total	25	20	8	53 (48*)

* Five research studies are on both ADHD and ASD

Out of 21 educational research studies are 6 from SEN Schools and 15 from mainstream schools. A more equal distribution is recognised from the research projects in total as illustrated in table 7.

Table 7 School setting

School setting	ADHD	ASD	AT	Total
Mainstream School (MAIN)	8	3	7	18
Special Educational Needs (SEN)	3	12	1	16

The literature review on AT for learners with ADHD or ASD has uncovered 69 research articles (table 5) of which 23 provides general insights on either AT, ADHD or ASD (table 8) and 46 papers with more specific findings on eight identified categories of technology-based interventions for the focus group (table 9).

Table 8 General findings

General findings on	Total
Assistive Technologies	8
ADHD	11
ASD	4
Total	23

Table 9 Specific findings

Specific findings on	Total	ADHD	ASD	LD
Technology Based Interventions for Memory Disabilities and/or Brain Train	5	5		
Technology Based Interventions for increasing focussing attention	8	4**	2**	4
Technology Based Interventions for Time and Task Management	5	3*	3*	
Technology Based Interventions for communication	5		5	
Technology Based Interventions for reading, writing, language and literacy skills	4	1	1	2
Technology Based Interventions for changing behaviour	4	2	2	
Technology Based Interventions for Group work and collaboration	5	1	4	
Other Important Issues on AT, ADHD or ASD	10	4	3	3
Total	46	20	20	9

* One paper on both ADHD and ASD

** Two papers on both ADHD and ASD

The technologies used as 'assistive' vary tremendously as displayed in table 10. Newly developed tools and deployment of these are overrepresented as long with technologies customised for specific SEN groups. It is significant, that no research on the use of generic, free online software or well distributed software, developed in a Universal Design for Learning approach (Hall et al., 2012), is found.

Table 10 Used assistive technologies

Hardware	Software
Computer	VOCA
iPad	vSKed
Personal Digital Assistants (PDA)	Online games
VideoCamera	Video + specific computer programs
iPod Touch	Join-In Suite
Interactive Whiteboard	ENGAGE games
Sound Field Amplification Systems (SFAS)	PECS
Augmented Night Castle	Prologue2Go
Tangible User Interfaces (TUIs)	TaskTracker
Personal FM System	Pictures
Kinect Remotes	Computer-based tasks
	HANDS
	Reading Trainer
	Kinem games

4. Findings

This section accounts for the 46 relevant studies, where findings provided insight into technology-based interventions for learners with attention and developmental deficits. The articles will be presented in seven categories of technology-based interventions (figure 1) supplemented by important issues and implications identified through this review.









Identified technology based interventions for							
1. Memory disabilities or brain training 	2. Increasing focussing attention 	3. Time and task management 	4. Communication 	5. Reading, writing, language and literacy skills 	6. Changing behaviour 	7. Group work and collaboration 	8. Other issues and implications 

Figure 1 Identified categories

4.1 Technology based interventions for memory disabilities or brain training

Table 11 Articles on memory disabilities or brain training

Title:	Author(s):	Year:
<i>Educational games based on distributed and tangible user interfaces to stimulate cognitive abilities in children with ADHD</i>	E. de la Guía, M. D. Lozano & V. M.R. Penichet	2015
<i>ICT and collaborative co-learning in preschool children who face memory difficulties</i>	A. S. Drigas, R.-E. Ioannidou, G. Kokkalia & M. D. Lytras	2015
<i>Working Memory and ADHD in Preschool Education. The Role of ICTs as a Diagnostic and Intervention Tool: An Overview</i>	G. Kokkalia & A. S. Drigas	2015
<i>Brain Games as a Potential Non-pharmaceutical Alternative for the Treatment of ADHD</i>	S. C. Wegrzyn, D. Herrington, T. Martin & A. B. Randolph	2012
<i>Empowering Children With ADHD Learning Disabilities With The Kinems Kinect Learning Games</i>	S. Retalis, T. Korpa, C. Skaloumpakas, M. Boloudakis, M. Kourakli, I. Altanis, F. Siameri, P. Papadopoulou, F. Lytra, P. Pervanidou	2014

The field of working memory and brain training is covered by both reviews and focussed studies. All five studies are targeted children with ADHD, with a general perspective on using the same approaches and concepts for other target groups.

When it comes to working memory, Drigas et al. (2014) identifies several studies which recommend use of technologies as diagnostic tools, for memory training or to support memory skills. They note as well, that immediately feedback from multimedia tools in general seems to allow a quicker pace of learning and improves memory skills. Earlier, working memory was regarded as a constant trait, but according to Kokkalia and Drigas (2015), recent research now suggests, it can be improved by adaptive and extended training.

The articles on brain training are concentrated on the use of games or novel software systems to support the improvement of focus learner's cognitive abilities or as a non-pharmaceutical alternative treatment of children with ADHD (Wegrzyn et al., 2012). The improvements are described as increased concentration and inhibited impulsivity (Retalis et al., 2014) or heightened memory and attention (de la Guía et al., 2015). The articles on working memory and brain training emphasise, that memory, cognitive skills and attention increase when learners with ADHD interact with Tangible User Interfaces (TUIs), gaming strategies and equipment, brain games and multimedia sources.

4.2 Technology based interventions for increasing focussing attention

Table 12 Articles on increasing focussing attention

Title:	Author(s):	Year:
<i>Acoustical barriers in classrooms: the impact of noise on performance in the classroom</i>	J. E. Dockrell & B. M. Shield	2006
<i>Effect of Sound-Field Amplification to Increase Compliance of Students With Emotional and Behaviour Disorders</i>	J. W. Maag & J. M. Anderson	2006
<i>The impact of sound-field amplification in mainstream cross-cultural classrooms: Part 1 Educational outcomes</i>	R. Massie & H. Dillon	2006a
<i>The impact of sound-field amplification in mainstream cross-cultural classrooms: Part 2 Teacher and child opinions</i>	R. Massie & H. Dillon	2006b
<i>The use of FM Systems for Children with Attention Deficit Disorder</i>	C. D. Updike	2006
<i>Sound-Field Amplification to Increase Compliance to Directions in Students with ADHD</i>	J. W. Maag & J. M. Anderson	2007
<i>The Impact of Sound-Field Systems on Learning and Attention in Elementary School Classrooms</i>	J. E. Dockrell & B. M. Shield	2012
<i>Personal FM systems for children with autism spectrum disorders (ASD) and/or attention-deficit hyperactivity disorder (ADHD): An initial investigation</i>	E. C. Schafer, L. Mathews, S. Mehta, M. Hill, A. Munoz, R. Bishop & M. Moloney	2013

While lacking attention is seen as a main problem with respect to academic issues, several research studies suggest awareness on background noises in classrooms to support learners focussing on relevant auditory stimuli. FM systems and Sound Field Amplification Systems (SFASs) seems to be promising ATs in cross-cultural classrooms (Massie and Dillon, 2006a; Massie and Dillon, 2006b), for SEN learners in general (Dockrell and Shield, 2012; Dockrell and Shield, 2006), or more specific for students with emotional and behaviour disorders (Maag and Anderson, 2006), ADHD and/or ASD (Updike, 2006; Maag and Anderson, 2007; Schafer et al., 2013). SFASs or FM systems amplify the voice of the teacher and allow the students to receive the spoken words in a closed or semi-closed headset, which reduces competing and disturbing input at different levels.

All eight studies in this category were conducted in real educational settings - in classrooms at mainstream schools where different kinds of learning disabilities among the students were represented or in kindergarten and SEN classes. The interventions were conducted by the teachers and targeted children with ADHD, ASD, and Learning Disabilities (LD).

The studies examined the field broadly with focus on both structural barriers in the learning environment and challenges regarding demonstrating learning effects for the target group within the qualitative studies. All eight studies report on positive impact. Dockrell and Shield (2006) describes how children in general perform worse in babbling and noisy classrooms, when it comes to processing pace and addressing verbal tasks, while SEN learners are '*differently negatively affected in the babble condition*' (Dockrell and Shield, 2006). Other improvements are identified, as illustrated in table 13.

Table 13 Identified improvements

Schafer et al. (2013)	Improved listening behaviour, better speech recognition and increased ontask behaviour for children with ASD and/or ADHD
Dockrell & Shield (2012)	Improved understanding of spoken language - but no academic attainments
Maag & Anderson (2006)	Increased speed with which students with emotional and behaviour disorders followed task demands
Massie & Dillin (2006b)	Improvement in attention, communication strategies and classroom behaviour
Massie & Dillin (2006a)	Beneficial effects in reading writing and numeracy
Maag & Anderson (2007)	Significant increased compliance for students with ADHD on task demands and alpha commands (clear, direct, specific instruction) and minor effect on beta commands (vague multiple instructions given simultaneously) and with high preference activities

Dockrell and Shield (2006) calls for a clear specification of the acceptable and enforceable noise level in a classroom, while Massie and Dillon, (2006a) suggests providing teachers with insight into the rationale and benefits of sound field amplification and to ensure adequate infrastructure at schools.

4.3 Technology based interventions for time and task management

Table 14 Articles on time and task management

Title:	Author(s):	Year:
<i>Classroom-Based Assistive Technology: Collective Use of Interactive Visual Schedules by Students with Autism</i>	M. Cramer, S. H. Hirano, M. Tentori, M. T. Yeganyan & G. R. Hayes	2011
<i>The TaskTracker: Assistive Technology for Task Completion</i>	V. E. Hribar	2011
<i>Using a Personal Digital Assistant to Increase Completion of Novel Tasks and Independent Transitioning by Students with Autism Spectrum Disorder</i>	L. C. Mechling & E. J. Savidge	2011
<i>Evaluating intervention using time aids in children with disabilities</i>	G. Janeslätt, A. Kottorp & M. Granlund	2014
<i>Development and User Satisfaction of Plan-IT Commander, a serious game for children with ADHD</i>	K. C. M. Bul, I. H. A. Franken, S. Van der Oord, P. M. Kato, M. Danckaerts, L. J. Vreeke, A. Willems, H. J. J. van Oers, R. van den Heuvel, R. van Slagmaat & A. Maras	2015

Limited research is available on using time and task management for focus learners (Janeslätt et al., 2014). Five articles address the topic but from different perspectives arguing for new technologies (Hribar, 2011), developing and testing technologies (Bul et al., 2015; Cramer et al., 2011), and

evaluating use of technologies and development of new classroom practices (Janeslatt et al., 2014; Mechling and Savidge, 2011).

The aids and technologies at play in the studies are diverse, from digital to analogue through to tangible. Likewise, a diversity regarding the target groups of the studies is identified covering children with LD, ADHD, ASD and few with double diagnoses. Most of the studies are qualitative and aiming at developing or improving the tools based on investigation.

The outcome from developing and testing aids and technologies at hand can merely be described as early indications on positive potential, but iterations and technical improvements are still needed. The positive indications are described as beneficial reactions by the children when working with the technologies or moderate gain in their independent task completion.

Time and task management seems to be a straightforward and concrete concept with great potential for supporting the focus group, but according to Janeslatt et al. (2014) three things must be considered: 1) Information and training of school personnel, 2) organisational support for professional cooperation of parent, teachers and therapist, and 3) insight and understanding of the learners' specific needs.

4.4 Technology based interventions for communication

Table 15 Articles on interventions for communication

Title:	Author(s):	Year:
<i>Interactive visual supports for children with autism</i>	G. R. Hayes, S. Hirano, G. Marcu, M. Monibi, D. H. Nguyen & M. Yeganyan	2010
<i>vSked: Evaluation of a System to Support Classroom Activities for Children with Autism</i>	S. H. Hirano, M. T. Yeganyan, G. Marcu, D. H. Nguyen, L. A. Boyd & G. R. Hayes	2010
<i>What children on the autism spectrum have to 'say' about using high-tech voice output communication aids (VOCAs) in an educational setting</i>	R. Checkley, N. Hodge, S. Chantler, K. Holmes & L. Reidy	2011
<i>Comparing the Picture Exchange Communication System and the iPad for Communication of Students with Autism Spectrum Disorder and Developmental Delay</i>	D. A. Hill & M. M. Flores	2014
<i>Evaluating iPad Technology for Enhancing Communication Skills of Children With Autism Spectrum Disorders</i>	T. K. Boyd, J. E. Hart Barnett & C. M. More	2015

Five papers on communication in this review are shared among one review and four novel studies. All of them targeted children with ASD or double diagnoses in preschool or in SEN settings. All together focus on supporting the learners in communicating and/or mediating utterances in SEN school or kindergarten contexts. Different communicational approaches and specific digital and analogue technologies are examined and evaluated. Positive findings are indicated, but the results from the studies are mixed.

Learners with ASD describe the Voice Output Communication Aid (VOCAs) as a '*pleasurable and motivating activity*', which seems to offer a potential for a broader developmental impact for this group of children (Checkley et al., 2011). Hirano and colleagues observed how a similar system (vSked) resulted in a reduction of time spend by the staff facilitating visual support, but at the same time improved the perceived quality and quantity of communication at

four levels: 1) student-specialist communication, 2) student-student interaction, 3) intra-specialist information sharing and communication but also 4) parent-specialist cooperation (Hirano et al., 2010).

It is evident from the literature that visual support can enable learners with ASD to communicate and learn more easily (Hayes et al., 2010). Though, when comparing analogue Visual Support Systems as e.g. Picture Exchange Communication Systems (PECS) with digital system on an iPad e.g. Prologue2Go, the results are blurred. Some ASD learners increase their requesting and have more independent initiations at the iPad - others do not.

“This difference is significant for the field because it shows that a low technology intervention can be as or more effective than a high technology device during the early stages of communication development”

(Hill and Flores, 2014).

A single review, which evaluates the iPad for enhancing communication skill, underlines that caregivers/teachers must understand both a child’s unique needs, the elements in the application and how the child’s use of it can be promoted or obstructed (Boyd et al., 2015).

4.5 Technology based interventions for reading, writing, language and literacy skills

Table 16 Articles on reading, writing, language and literacy skills

Title:	Author(s):	Year:
<i>Do children with reading delay benefit from the use of personal FM system in the classroom?</i>	S. C. Purdy, J. L. Smart, M. Baily & M. Sharma	2009
<i>A combined Computerized Approach to Improve Fluency on a Dyslexic Reader – Evidence from a Case Study</i>	S. Pinnelli & C. Sorrentino	2012
<i>Use of Images in Instructional Technology for Children with Attentional Difficulties</i>	H. W. Kang, S. S. Zentall & T. L. Burton	2007
<i>Use of computer-based interventions to improve literacy skills in students with autism spectrum disorders: A systematic Review (Ramdoss et al., 2011)</i>	S. Ramdoss, A. Mulloy, R. Lang, M. O'Reilly, J. Sigafoos, G. Lancioni, R. Didden & F. El Zein	2011

Two research studies, focussing on reading and writing, are broadly targeting children with general LD, while two studies on language and literacy skills are levelled at learners with ADHD or ASD.

An Italian qualitative study highlights the use of a specific online software, Reading Trainer, but brings primarily focus on the role of the teacher and the pedagogical activities when working with the software (Pinnelli and Sorrentino, 2012).

Purdy et al. (2009) uses a personal FM system in a mainstream school context and examines how reading and comprehension skills increases for children

with learning difficulties. The study demonstrates positive indications in both perception and literacy, but no measurable improvements in reading age during the interventions.

Kang et al. (2007) examines the value of images regarding enhancing attention and on-task behaviour during instructions for children with ADHD in a math class. The intervention indicates improved performance by children with ADHD when using images compared to peers without images. The more additional information the images contain, the better are the student's math performance.

The review from Ramdoss et al. (2011) on children with ASD analyses twelve studies on computer-based interventions and identifies both positive and negative outcome. Four studies cover both learners with ADHD and ASD. Mixed results indicate that it is a challenging and complex task to identify and select general technologies to improve the basic learning skills.

“No single intervention for children with ADHD [or ASD] is effective, due to the myriad of symptoms.”

(Fenstermacher et al., 2006)

4.6 Technology based interventions for changing behaviour

Table 17 Articles on changing behaviour

Categorised articles:	Author(s):	Year:
<i>Effectiveness of a Computer-Facilitated, Interactive Social Skills Training Program for Boys with Attention Deficit Hyperactivity Disorder</i>	K. Fenstermacher, D. Olympia & S. M. Sheridan	2006
<i>Assisting children with Attention Deficit Hyperactivity Disorder actively reduces limb hyperactive behavior with a Nintendo Wii Remote Controller through controlling environmental stimulation</i>	C.-H. Shih, J.-C. Yeh, C.-L. Shih & M.-L. Chang	2011
<i>Key factors mediating the use of a mobile technology tool designed to develop social and life skills in children with Autistic Spectrum Disorders</i>	J. Mintz, C. Branch, C. March & S. Lerman	2012
<i>Using Video Social Stories to Increase Task Engagement for Middle School Students With Autism Spectrum Disorders</i>	D. F. Cihak, L. K. Kildare, C. C. Smith, D. D. McMahon & L. Quinn-Brown	2012

Four research studies concentrate on the potentials for tools, methods, and technologies to support learners to change behaviour towards managing tasks, join a learning situation or develop social skills. The studies are either oriented on learners with ADHD or ASD.

Cihak et al. (2012) and Mintz et al. (2012) focused on the role of the teacher when teaching learners with ASD. In both studies, teachers were responsible for interventions with specific digital technologies: A mobile cognitive support application for Smartphones (HANDS) (Mintz et al., 2012) or self-modelling through Video Social Stories (Cihak et al., 2012). The results from Cihak and colleagues (2012) display the use of Video Social Stories for learners with ASD as very promising. First, because the learners improved their task engagement and task completion in a mainstream-school context. Secondly, because the

interventions were reported as socially accepted by all participants. Same positive indications are presented by Mintz et al. (2012) where the HANDS application helps learners with ASD to manage e.g. morning preparation tasks effectively and support them in a way, where they are observed calmer and more able to deal with social situations.

Fenstermacher et al. (2006) examines the effect of an integration of video- and computer-based social simulations, where instructional content presents stimulus events in mainstream school context targeted learners with ADHD. The instructions are made in close fidelity with the actual phenomenon of social interaction. The study focuses on treatment and finds the method promising for professionals to address social problem-solving difficulties together with focus learners.

Shih et al. (2011) presents a study on how Nintendo Wii controllers correct limb behaviour by learners with ADHD. The findings show an increased duration in static postures, but since the interventions are facilitated by researchers in a laboratory context, the findings must merely be considered as basis for further development in learning or school settings.

4.7 Technology based interventions for group work and collaboration

Table 18 Articles on group work and collaboration

Title:	Author(s):	Year:
<i>Effects of computer collaborative group work on peer acceptance of a junior pupil with attention deficit hyperactivity disorder</i>	T. S. Tan & W. S. Cheung	2008
<i>In my own Words: Configuration of Tangibles, Object Interaction and Children with Autism</i>	W. Farr, N. Yuill, E. Harris & E. Hinske	2010
<i>Social benefits of a tangible user interface for children with Autistic Spectrum Conditions</i>	W. Farr, N. Yuill, E. Harris & H. Raffle	2010
<i>Dimensions of Collaboration on a Tabletop Interface for Children with Autism Spectrum Disorder</i>	L. Giusti, M. Zancanaro, E. Gal & P. L. T. Weiss	2011
<i>Increasing social engagement in children with high-functioning autism spectrum disorder using collaborative technologies in the school environment</i>	N. Bauminger-Zviely, S. Eden, M. Zancanaro, P. L. Weiss & E. Gal	2013

Four out of five studies categorised as interventions for group work and collaboration targeted learners with ASD. Only two of them take place in educational contexts, while three are aimed at development of tools for play or treatment, as e.g. Giusti et al. (2011) who presents important focus points in development of software to enhance collaboration in therapeutic contexts.

Farr et al. (2010a, 2010b) publish two different studies which both examines how tangible technologies facilitate cooperative play among learners with ASD. The studies find that digital technologies embedded in Tangible User Interfaces (TUIs) facilitate more collaborative play than traditional analogue toys (Farr et al., 2010a) and underline the positive effects, when the technologies are configurable (Farr et al., 2010b).

Bauminger-Zviely et al. (2013) analyses how school-based technology interventions combined with cognitive behavioural therapy improve different

aspects of group work and collaboration for learners with high functioning ASD. The study finds improvements consisting of more active solutions to social problems and more appropriate understanding of collaboration and social conversation, while the advances in the learners' actual social engagement are more diffuse.

Mavrou (2012) examines how peer acceptance and non-acceptance occur in computer-supported collaborative learning activities and identifies four types of reactions as 1) response to peer, 2) peer involvement, 3) individualistic behaviour, and 4) peer rejection. The study concluded that rejection and individualistic behaviour primarily happens because of unwanted behaviour between group members and emphasizes the importance of roles and rules to support collaborative learning processes. A peer acceptance model is introduced, which rank motivation and engagement as vital for the effectiveness in the collaboration.

Tan and Cheungs (2008) qualitative study on one learner with ADHD in a mainstream school setting examines how collaborative group work on computers facilitated by an adult affects the learner. The study finds a potential in computer collaborative group work, but underlines the importance of teachers' knowledge and expertise, when working with children with ADHD:

“Teachers play a vital role. They need to be very organised, have expert skills, have routines well established and be adaptable to ever-changing factors and conditions in the mainstream classroom.”

(Tan and Cheungs, 2008)

4.8 Important issues and implications

Table 19 Important issues and implications

Title:	Author(s):	Year:
<i>Assistive Technology and Literacy Learning: Reflections of Parents and Children</i>	T. Jeffs, M. Behrmann & B. Bannan-Ritland	2006
<i>Inadequacies in computer access using assistive technology devices in profoundly disabled individuals: An overview of the current literature</i>	B. S. Scott	2007
<i>Software and Technologies Designed for People with Autism: What do users want?</i>	C. Putnam & L. Chong	2008
<i>Review of Research: Individuals with ADHD Lost in Hyperspace</i>	R. Harlin & V. Brown	2009
<i>Designing for ADHD: in search of guidelines</i>	L. McKnight	2010
<i>SketchUp: A Technology Tool to Facilitate Intergenerational Family Relationships for Children with Autism Spectrum Disorders (ASD)</i>	C. Wright, M. L. Diener, L. Dunn, S. D. Wright, L. Linnell, K. Newbold, V. D'Astous & D. Rafferty	2011
<i>Challenges, Opportunities and Future Perspectives in Including Children with disabilities in the Design of Interactive Technology</i>	C. Freuenberger, J. Good & A. Alcorn	2012
<i>Computer use in educational activities by students with ADHD</i>	V. Bolic, H. Lindstrom, N. Thelin, A. Kjellberg & H. Hemmingsson	2013
<i>Attention Deficit Disorder (ADHD): Primary school teachers' knowledge of symptoms, treatment and managing classroom behaviour</i>	B. Topkin, N. V. Roman & K. Mwaba	2015
<i>Comment on Technology-Based Intervention Research for Individuals on the Autism Spectrum</i>	J. P. McCleery	2015

Even though many studies reach the conclusion that technologies can support, assist or enable learning, it is difficult for teachers to choose and know how to interact with technologies to achieve similarly positive results in their own educational practice (Pinnelli and Sorrentino, 2012). In this final section different issues and implications are gathered to enlightening important perspectives and implications uncovered throughout the review.

Bolic et al. (2013) investigates access to and satisfaction with the use of technologies among students with ADHD. The students with ADHD wish to use computers more often and for more educational activities but indicate that schools are more prepared to meet the needs of students with physical disabilities than those with ADHD.

Frauenberger et al. (2012) suggests a higher focus on participatory design approaches to reach increased understanding of the end-user's requirements, more realistic expectations in the target groups and a higher empowerment of marginalised groups. Likewise pleads Hoppestad (2007) for an ongoing, person centred, individualised and detailed assessment approach to utilise the potential of Assistive Technologies when it comes to successful functioning in real world environment. Hoppestad (2007) suggests considering both student, environment, task and technology and states, that the diversity of needs calls for a Universal Design for Learning (Hall et al., 2012) approach.

Putnam and Chong's (2008) user survey uncovers the desires of grownups with ASD and parents to children with ASD regarding development of new software and technologies. They report technologies as powerful and of interest for people with ASD, but ask for tools to develop social, academic and organisational skills.

Wright et al. (2011) emphasises the importance of family involvement and suggests

“interventions that promote self-efficacy may improve multiple dimensions of family functioning”.

Wright et al. (2011)

Same perspective is found by Jeffs et al. (2006), who examines how parents and children with disabilities in reading and/or writing developed new learning strategies together and fostered a shared understanding and awareness to what worked well for the individual child. The assistive technologies used in combination with Internet resources provided the children with opportunities to learn in new ways. Learning was enabled. Simultaneous they identify barriers for adequate utilisation of Assistive Technologies and SEN services in schools setting as shown in table 20:

Table 20 Barriers for utilising AT in schools

1.	The growing number of possible useful emerging technologies make it difficult for teachers to be up-to-date
2.	A lack of training and integration of new technologies
3.	A lack of school personnel trained to recommend and provide support for use of Assistive Technologies
4.	Not enough sufficient trained SEN teachers and a lack of evaluation and support for staff

Teacher training is mentioned in many studies, but Topkin et al. (2015) demonstrates, that only 45% of the teachers have sufficient knowledge of symptoms, treatment and strategies for management of classroom behaviours regarding children with ADHD. They suggest continuous teacher training, more research and theory in classroom management and use of instructional methods, that respond to the learners' academic needs combined with a positive relationship between learner and educator to achieve a more positive outcome for learners with ADHD

Harlin and Brown (2009) requests awareness on how deficits experienced in individuals with ADHD might make it difficult for them to navigate, plan and overview hypermedia learning resources. The authors recommend teachers to reduce the cognitive load on students with ADHD, use highly structured instructions, and assist them in becoming familiar with the navigation, because

“when navigation becomes confusing, students focus cognitive resources in interpreting the navigational cues rather than in the content.”

(Harlin and Brown, 2009)

Finally, McKnight (2010) provides us in table 21 with detailed guidelines for teachers to follow when designing learning content and learning environments for students with ADHD. The guidelines are based on recommendations from support agencies, and are not being claimed as

scientific effective, yet there seem to be some overlap from what is already known from commonly usability guidelines from software design.

Table 21 Guidelines for designing learning content for learners with ADHD

1.	Design materials so the layout is neat and uncluttered.
2.	Provide a 'calm' environment, with soothing colours. No decorations or distractions.
3.	Provide a high-reinforcement environment - reward good behaviour and compliment of all tasks that are asked of the children, using positive language.
4.	Organise items in an orderly way.
5.	Distinguish important information by putting it in bold of colour. Signpost sections and group related information into panels.
6.	Use large print (12-14 point) and a clear sans-serif font such as Arial.
7.	Help pupils follow text by writing/highlighting alterante lines in different colours.
8.	If the pupil needs to work through a series of questions, help them keep their place by using a marker.
9.	Use brief and clear instructions.
10.	Allow ample rest periods and exercise breaks.
11.	Have a workstation that is enclosed, in a soundproof environment, with few distractions around.
12.	Keep technology shut away unless it is being used.
13.	Keep to a routine, e.g. do not change teachers.
14.	Minimise surprises.
15.	Maintain eye contact.

5. Discussion and conclusion

This review has identified 69 articles on assistive learning technologies for learners with ADHD and ASD, where only 26 studies were conducted in authentic learning contexts; 15 at SEN schools and 11 in basic schools, which calls for much more research on AT in mainstream learning and school settings. Due to the small number of studies at basic schools, studies in SEN settings, on technology development and from use of technology-based interventions in treatment settings are included to inform broadly on possibilities for using AT to support learners with ADHD and ASD to participate and contribute in educational settings. Using this approach seven categories of assisting learning technologies or computer-based interventions for learning are identified as illustrated in figure 2:








Seven identified categories of technology based interventions						
1. Memory disabilities or brain training 	2. Increasing focussing attention 	3. Time and task management 	4. Communication 	5. Reading, writing, language and literacy skills 	6. Changing behaviour 	7. Group work and collaboration 

Figure 2 Identified technology-based interventions

Technologies are recommended as diagnostic tools for **memory difficulties** or to train and support weak memory. Technologies which provide immediately feedback, digital games, Tangible User Interfaces (TUIs) and

multimedia sources have shown to give rise to a quicker pace in task solving, improved memory and cognitive skills, increased attention and concentration and, inhibited impulsivity.

Awareness on background noises and use of Sound Field Amplification Systems (SFAS) have increased **focussing attention** and improved understanding, classroom behaviour, speech recognition, reading, writing, numeracy and task completion by the focus group.

Learners with ADHD and ASD have reacted positively on **time and task management technologies**, which have provided a moderate gain in independent task completion.

Technologies with visual support have shown to support **communication**, allowed learning to happen more easily and saved time for the staff. The communication has both qualitatively and quantitatively been increased between students, students and specialist, specialists and parent and, among specialists.

The perception and **literacy skills** by learners have been improved when using SFAS, while multimodality materials with images have improved their performances. No improvement in **reading skills** was measured during these research interventions.

Video social stories and visual structuring tools have shown to **change focus learners' behaviour**. Task engagement and completion was improved, they were acting calmer and were dealing better with the social situation. The technologies might have supported them to enhance their surplus of mental resources.

Group work and collaboration in play and learning has shown to be improved, when configurable and tangible user interfaces are included. Though, it seems of importance, that roles and rules are very specific during collaboration and teachers are present to act as role models and mediators. Students' motivation and engagement seem to be vital as well.

Regardless valuable benefits when using technologies for learners with ADHD or ASD, it does not seem to be an easy task to implement and start using these new approaches. The focus learners react in general very positively on the technologies and ask for a wider use of those, but e.g. learners with ADHD witness, that they experience a lower priority related to learners with physical disabilities, when it comes to support and access to assistive technologies.

Most of studies are pointing at teacher competences as an important gatekeeper for taking advantage of technologies in educational settings (e.g. Topkin et al., 2015; McKnight and Davies, 2012; Tan and Cheungs, 2008). The infinite stream of new technologies makes it difficult for teachers to overview the many possibilities, choose the right tools and develop necessary user competences. There is a call for a higher awareness on support and training of teacher/caregivers/parents, but also a deeper understanding of the individual

learners' specific needs. A more participatory approach is suggested, where end-users are taking an active part in choosing and customising their individualised supportive tools and families are involved as valuable stakeholders.

To utilise the potential of AT, it seems necessary to look holistically at both the individual learner, the environment, the task, and the technologies when developing sustainable solutions. It is important to appreciate, that technology-based classroom interventions only have low effect if any, if necessary cognitive or behavioural therapy is missing. Technologies can support and develop a deployed pedagogy, but throughout this review it has been mentioned, that teachers' professional knowledge and expertise on both SEN pedagogic and technology is vital.

The number of studies in each category in this review is in general very low and the number of participants few. Even though promising use of technologies are identified, the small collection of studies leaves with very mixed results. Many studies included in the review are developing or testing new technologies. Different kinds of ATs have been useful as diagnostic, training or supporting tools, but a lack of research in authentic educational settings on e.g. diagnosing and supporting children with memory difficulties or strategies for empowerment of focus learners in digital group work and collaboration, communication and production is noticed. Consequently, the authors suggest a wider research focus on pedagogical interventions with assistive technologies in a Universal Design for Learning (UDL) approach, where diversity is expected and accepted, where learners are regarded as having different needs instead of disorders and generic digital technologies are provided for all learners.

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