Online Supplemental Material:

Self-directed speech and self-regulation in childhood neurodevelopmental disorders: Current findings and future directions

Context

This document outlines the search strategy utilized for this systematic review along with a tabulated summary of extracted data from 19 peer-reviewed research articles.

Table S1

Search Strategy

Self-talk OR "Self Talk" OR "Inner speech" OR "Private speech" OR "Self-instructional speech" OR "Self instructional speech" OR "Self-regulatory speech" OR "Self regulatory speech" OR "Overt speech" OR "Covert Speech"
AND
Child* OR Pre-school OR Preschool OR School-age OR "School Age" OR Kindergarten OR "Primary school" OR "Elementary school"
AND
"Attention Deficit" OR "Attentional Disorder" OR ADHD OR ADD OR AD/HD OR Autism* OR ASD OR Asperger* OR "Neurodevelopmental Disab*" OR "Neurodevelopmental Delay*" OR "Neurodevelopmental Disorder*" OR "Neurodevelopmental Condition*" OR "Language Impairment*" OR "Language Delay*" OR "Language Disorder*" OR "Specific Language Impairment" OR "Speech-Language Impairment*" OR "Speech and Language Impairment*" OR "Speech and Language Disorder*" OR "Speech Language Disorder*" OR "Speech-Language Disorder*" OR "Speech and Language Delay*" OR "Speech-Language Delay*" OR "Speech Disorder*" OR Behavio* OR Self-regulation* OR "Self Regulation" OR Emotion* OR "Social Skills" OR "Developmental Disorder*" OR "Developmental Weakness*" OR "Learning Challenge*" OR "Intellectual Disab*" OR "Intellectual Developmental Disab*" OR "Mental Retardation"

Table S2

Research on Self-Directed Speech in Developmental Language Disorder

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Sturn & Johnson (1999) ***	DLD (n=6) Age (M): 4;10 NV IQ (M): 110 TD Same Age Controls (n=6) Age (M): 4;7 NV IQ (M): 108 TD Younger Age Controls: (n=6) Age (M): 3;6 NV IQ (M): 103	Fantasy play in dyads o Children were instructed to build a bridge o Children in dyads were familiar o At least one member of each dyad had typical language development	<u>Coding</u> Verbalization during play task was coded for: (a) Relevance: narrow/broad/irrelevant (b) Function: regulating/affective/word play as per Furrow (1992) (c) Addressee: private/social as per Diaz (1992) <u>Measurement</u> 1. Amount and proportion of utterances containing content that was relevant and problem solving 2. Amount and proportion of utterances that were private or social in form	Interpretation of results solely in terms of private speech is difficult as much of the analysis encompasses both private and social speech. o More problem solving speech overall was private than social. o Group differences overall reflect differences in speech quantity (private and social) rather than cognitively oriented speech. o In the control group, a higher proportion of problem solving speech (private and social) was associated with greater cognitive efficiency (i.e., speed and accuracy of responses). o In the DLD group, a higher proportion of problem solving speech (private and social) was associated with reduced cognitive efficiency (i.e., speed and accuracy of responses).

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Lidstone, Meins & Fernyhough (2012) ****	DLD (n=21) Age (M): 9;5 Gender: Male (n=16) and Female (n=5) NV IQ (M): 96 Expressive Language (M): 65 Receptive Language (M): 77 TD (n=21) Age (M): 9;4 Gender: Male (n=12) and Female (n=9) NV IQ (M): 96 Expressive Language (M): 95 Receptive Language (M): 98	Tower of London (TOL) and digit span procedure under 3 conditions: 1. Baseline: No manipulation 2. Articulatory suppression: Repetition of 'Monday' at pace of one per second 3. Foot tapping: Tapping a foot pedal at pace of one per second	<u>Coding</u> Verbalization in baseline condition was coded for: (a) Addressee: private/social as per Winsler, Fernyhough, McClaren & Way (2005) (b) Relevance: 3 levels as per Berk (1986) (c) Level of internalization: 5 levels from overt to inaudible as adapted from Berk (1986) <u>Measurement</u> 1. Frequency of private speech production 2. Level of internalization of private speech 3. Recruitment of inner speech suggested by presence and extent of performance cost in response to articulatory suppression	o Group differences reflect delayed internalization of self-directed speech in the DLD group. o No significant group differences in performance costs due to articulatory suppression, suggesting similar use of inner speech during TOL. o Findings suggest delay rather than deviance in the development of self-directed speech in the DLD group.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Kuvalja, Verma & Whitebread (2014) ***	DLD (n=12) Age: 6 years NV IQ: 1SD below mean or greater (i.e., >85) VMA: 1.25SD below mean or lower TD (n=12) Age: 6 years NV IQ: 1SD below mean or greater (i.e., >85) VMA: not specified but no difficulties as per school report	Lego Planning Task o Lego town with 9 buildings o Children build Lego postman and are provided with a list of 6 buildings to visit out of a possible 9 o Children must use the shortest route rather than simply follow the list	<u>Coding</u> Verbal and non-verbal behavior was coded (a) Verbal behavior coded as per 11 SDS form or content categories generated by researchers in response to data (b) Non-verbal behavior coded as per 13 categories generated by researchers in response to data <u>Measurement</u> 1. Frequency analysis (i.e., frequency of private speech occurrence per/min) 2. Lag sequential analysis (i.e., frequency of co-occurring events in researcher specified time window) 3. T-pattern analysis (i.e., search for significantly co-occurring patterns)	o Overall children with DLD took longer to complete the task and used more private speech. o Frequency analysis revealed no significant group difference in the rate of private speech. o T-pattern analysis revealed children with DLD displayed verbal-nonverbal behavior patterns that were greater in number and complexity than that of TD children.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Aziz, Fletcher & Bayliss (2017) ****	DLD (n=91) Age (M): 5;3 Gender: Male (n=62) and Female (n=29) NV IQ (M): 103.34 Children's Communication Checklist 2 Score (M): 47.72 TD (n=81) Age (M): 5;6 Gender: Male (n=48) and Female (n=33) NV IQ (M): 108.52 Children's Communication Checklist 2 Score (M): 77.93	Performance (accuracy) and private speech use are recorded during a Tower of London (TOL) task.	<u>Coding</u> Verbalization was coded for: (a) Task relevance: planning or non-planning (b) Addressee: private/social (c) Inaudible muttering: unintelligible whispering, muttering and silent lip movements <u>Measurement</u> 1. Proportion of relevant or irrelevant utterances 2. Mean utterance per TOL item for task relevant (a) social speech, (b) private speech and (c) inaudible muttering 3. Number of items with task relevant speech (i.e., social, private and inaudible muttering) 4. Proportion of children that are (1) silent, (2) always use task relevant speech, and (3) sometimes use task relevant speech	○ Both TD children and children with DLD predominately used task relevant speech during the TOL. ○ TD children used more inaudible muttering than children with DLD across kindergarten, pre-primary and grade 1. ○ There were no group or grade related differences in private speech use. ○ There were no overall group differences in social speech. TD children demonstrated a significant reduction in social speech between kindergarten and pre-primary that was not evident in the DLD group. ○ Children with DLD and hyperactivity used significantly more private speech and performed worse on the TOL than children with DLD without hyperactivity. ○ More children with DLD performed better with task relevant speech than when silent. The majority of TD children performed comparably regardless of whether they were silent or used task relevant speech.

Note. DLD = Developmental Language Disorder (also known as Specific Language Impairment); TD = Typically Developing; SDS = Self-Directed Speech; SD = Standard Deviation;
NV IQ = Non-verbal IQ; VMA = Verbal Mental Age; (n) = Number; (M) = Mean; Age: Year;Month.
Mixed Methods Appraisal Tool (MMAT) Rating (Pace et al., 2011): * = 1; ** = 2; *** = 3; **** = 4

Table S3

Research on Self-Directed Speech in Children with Autism Spectrum Disorder

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Schaerlaekens & Swillen (1997) **	ASD (n=3) **Case Study 1:** Gender: Female Age: 7;5 **Case Study 2:** Gender: Male Age: 6;1 **Case Study 3:** Gender: Male Age: 4;9	Crib speech (i.e., pre-sleep private speech) was recorded at bed time o A cordless mini-cassette with microphone was placed under the child's bed o Parents switched on the recording device when putting their child to bed and switched it off two hours later o Parents continued to record each night until 45mins of private speech was recorded	All crib speech (i.e., pre-sleep private speech) was recorded and transcribed. All data was considered qualitatively. Researchers comment on the form, grammaticality and content of the pre-sleep private speech.	o Researchers interpret the emergence of crib speech as developmentally delayed in the cases under study based on parental report. o Parental reports suggest individual differences in frequency of crib speech use. o Crib speech samples were mostly grammatical. o Recorded crib speech content referred to the sleep ritual and important events from the day. o The crib speech of the three children with ASD was described as rigid and monologic in form, while that of two further children described as psychotic contained both monologic and dialogic components.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Whitehouse, Mayberry & Durkin (2006) ****	ASD (n=20); Age (M): 10;11 Gender: Male VMA (M): 9;5 Raven's Standard Progressive Matrices Raw Score (M): 38.1 TD (n=20); Age (M): 8;4 Gender: Male VMA (M): 9;2 Raven's Standard Progressive Matrices Raw Score (M): 35.5 NOTE: 3 additional participants were included in each group for experiments 2 and 3	<u>1. Picture Superiority Effect:</u> 10 picture or 10 print stimuli were presented serially, followed by a 1-minute filler task and recall <u>2. Word Length Effect:</u> Serial recall of 5 items in pictures under encoding (silent vs label) and word length (short vs long) conditions <u>3. Task Switching:</u> Arithmetic problems in blocked and task switching trials with and without articulatory suppression	<u>Measurement</u> Recruitment of inner speech suggested by presence and extent of picture superiority and word length effects as well as performance costs in response to articulatory suppression.	○ Children with ASD demonstrated a significantly lesser picture superiority effect, suggesting interruption in the recruitment of inner speech. ○ Children with ASD demonstrated a significantly lesser word length effect, suggesting interruption in the recruitment of inner speech. ○ In comparing the overt labeling (i.e., induced overt SDS) condition to the silent condition in experiment 2, children with ASD displayed a significantly greater word length effect, but still less than that of TD children. ○ Children with ASD took significantly less time than TD controls to complete the arithmetic problems (blocked and task switching) under articulatory suppression, suggesting reduced recruitment of inner speech.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Winsler, Abar, Feder, Schunn & Rubio (2007) **** NOTE: This study is also included in the ADHD section.	ASD (n=33) Age (M): 11 Gender: Male (n=32) and Female (n=1) Medicated: 57% of sample ADHD (n=21) Age (M): 11;7 Gender: Male (n=13) and Female (n=8) Medicated: 90% of sample *Note:* Testing during washout period for those medicated due to ADHD symptoms. No washout for medication use to treat other symptoms (e.g., anxiety) TD (n=28) Age (M): 10;4 Gender: Male (n=19) and Female (n=9)	Two computer administered tasks of executive functioning (i.e., Wisconsin Card Sorting Task and the Building Sticks Task)	<u>Coding</u> All child speech utterances were coded according to: (a) Addressee: social or private (b) Relevance and degree of internalization using 3 levels as per Berk (1986) <u>Measurement</u> 1. Frequency of social speech per minute 2. Frequency of private speech per minute 3. Frequency of Berk's (1986) categories per minute 4. Proportion of private speech within each of Berk's (1986) categories	○ Children with ASD and ADHD experienced significantly greater challenge with executive functioning compared to TD controls as indicated on measures of the BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000) and task performance. ○ The majority of children used private speech within executive functioning tasks with no significant group differences. ○ When all children made errors within tasks they were more likely to use private speech. ○ On the Card Sort task children with ASD and ADHD used proportionately more overt and less partially internalized private speech than TD controls. ○ Children with ASD were more likely to get items correct on the Card Sort Task when talking and were more likely to make perseverative errors when silent. ○ Unlike TD controls, children with ASD did not display an age related decline in overt and partially internalized private speech use.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Williams, Happe & Jarrold (2008) ***	ASD (n=25) Age (M): 12;3 Gender: Male (n=22) and Female (n=3) NV IQ (M): 76.84 V IQ (M): 77.16 VMA (M): 8;9 Comparison Group (n=20) General Learning Disability (n=18) and TD (n=2) Age (M): 12;1 Gender: Male (n=15) and Female (n=5) NV IQ (M): 74.39[#] V IQ (M): 73.20 VMA (M): 8;4 [#] - based on 18 participants	A serial recall task using visual stimuli that were (1) phonologically similar, (2) visuospatially similar or (3) control stimuli with neither form of similarity o 24 pictures divided into 3 sets o Each condition was completed and the order of card presentation counterbalanced o Participants were instructed to remain silent o Performance scored as span performance	<u>Measurement</u> A phonological similarity effect evidenced as reduced performance in response to phonological similarity is considered to reflect recruitment of verbal encoding/inner speech. A visuospatial similarity effect evidenced as reduced performance in response to visuospatial similarity is considered to reflect a reliance on visual over verbal encoding.	o The main effect of condition was not significant, as overall participants were not reliably affected by visual or phonological similarity. o The main effect of diagnosis was not significant, showing that overall children with ASD showed a similar pattern of recall to the comparison group (i.e., primarily general learning disability). o The main effect of verbal mental age was significant across diagnostic groups: - Children from both groups with a verbal mental age above 7 years displayed a phonological similarity effect, suggesting inner speech recruitment. - Children from both groups with a verbal mental age below 7 years displayed a visuospatial similarity, suggesting a reliance of visual encoding over inner speech recruitment.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Lidstone, Fernyhough, Meins &Whitehouse (2009) *** NOTE: This paper provides a reanalysis of Experiment 3 from Whitehouse, Mayberry & Dunkin (2006)	**ASD Group** Gender: Male ASD **NV=V** Group (n=12) Age (M): 11;4 Non-Verbal Mental Age (M): 11;3 Verbal Mental Age (M): 10;11 ASD **NV>V** Group (n=8) Age (M): 10;5 Non-Verbal Mental Age (M): 12;3 Verbal Mental Age (M): 7;9 **TD Group** Gender: Male TD **NV=V** Group (n=15) Age (M): 8;4 Non-Verbal Mental Age (M): 10;7 Verbal Mental Age (M): 9 TD **NV>V** Group (n=8) Age (M): 8;4 Gender: Male Non-Verbal Mental Age (M): 11;9 Verbal Mental Age (M): 8;5	Task switching in sets of 20 arithmetic problems with and without articulatory suppression o Arithmetic problems with function and equals signs omitted and instruction to alternate between addition and subtraction o Control condition requires completion of problems quickly and accurately o Articulatory suppression condition requires completion of problems whilst repeating 'Monday' in pace with metronome	<u>Measurement</u> Recruitment of inner speech suggested by presence and extent of performance costs (i.e., response time) in response to articulatory suppression.	o There was no main effect of cognitive profile on articulatory suppression interference. o A main effect existed for the ASD group but this was qualified by a significant interaction with cognitive profile type. In the ASD group the articulatory suppression interference was lower in the NV>V group than the NV=V group. o Overall, the only group to display no significant articulatory suppression interference was the ASD NV>V group. o Further analysis indicates that a speed-accuracy trade off or language level alone did not explain these findings. o Researchers suggest that children with ASD and a predominately NV>V profile in particular do not recruit inner speech for arithmetic task switching.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Holland & Low (2010) ***	ASD (n=13) Age (M): 10;9 Gender: Not Specified VMA (M): 11;5 TD (n=13) Age (M): 9;4 Gender: Not Specified VMA (M): 11;3	<u>1. Task Switching:</u> Arithmetic problems in blocked and task switching trials under silent, articulatory suppression (i.e., verbalization of days of week in pace with metronome) and visuospatial suppression (i.e., tapping 4 blocked in specified pattern in pace with metronome) conditions <u>2. Tower of Hanoi:</u> Tower of Hanoi task under silent, articulatory suppression and visuospatial suppression conditions.	<u>Measurement</u> 1. Recruitment of inner speech to service executive control is suggested by presence and extent of performance costs (i.e., response time) in response to articulatory suppression. 2. Recruitment of visuospatial representations to service executive control is suggested by presence and extent of performance costs (i.e., response time) in response to visuospatial suppression.	○ In the alternating arithmetic and Tower of Hanoi tasks TD children displayed a significantly slower completion time under articulatory suppression but children with ASD did not. ○ In the alternating arithmetic and Tower of Hanoi tasks children with ASD and TD controls were equally affected by visuospatial suppression. ○ Researchers suggest that children with ASD do not recruit inner speech to the same extent as TD children, but do recruit visuospatial representations to service executive control.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Williams & Jarrold (2010) *** NOTE: This paper provides a reanalysis of data from Williams, Happe & Jarrold (2008)	**ASD Group (n=25)** ASD **NV≤V** Group (n=18) Age (M): 12;2 NV IQ (M): 70 V IQ: (M) 79.94 ASD **NV>V** (n=7) Age (M): 12;6 NV IQ (M): 94.43 V IQ (M): 70 **Comparison Group (n=18)** General learning Disability (n=16) and TD (n=2) Comparison **NV≤V** Group (n=12) Age (M): 12;8 NV IQ (M): 65.92 V IQ (M): 72.42 Comparison **NV>V** (n=6) Age (M): 11;2 NV IQ (M): 91.33 V IQ (M): 75.83	A serial recall task using visual stimuli that were (1) phonologically similar or (2) control stimuli with no phonological similarity o 16 pictures divided into 2 sets o Each condition was completed and the order of card presentation counterbalanced o Participants were instructed to remain silent o Performance scored as span performance	<u>Measurement</u> A phonological similarity effect evidenced as reduced performance in response to phonological similarity is considered to reflect recruitment of inner speech.	o Reanalysis of the original data suggested that regardless of diagnostic group, cognitive profile was a significant predictor of phonological similarity effect. o Those with a NV≤V cognitive profile (i.e., predominately verbal) displayed a greater phonological similarity effect than those with a NV>V cognitive profile (i.e., predominately non-verbal). o However much of this association was dependent on verbal mental age. Verbal mental age was a significant predictor of phonological similarity effect, independent of cognitive profile. o Researchers suggest that verbal mental age remains the critical predictor of inner speech recruitment.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Russell-Smith, Comerford, Mayberry & Whitehouse (2014) ****	ASD (n=17) Age (M): 11;11 Gender: Male (n=14) and Female (n=3) NV IQ (M): 101.6 V IQ (M): 101.4 TD (n=18) Age (M): 10;8 Gender: Male (n=16) and Female (n=2) NV IQ (M): 102.9 V IQ (M): 109.6	Wisconsin Card Sorting Task under four conditions which were counterbalanced across participants: 1. Silent (Baseline): Standard conditions without instruction to use or inhibit inner speech 2. Articulatory Suppression (AS): Repetition of Monday in pace with metronome 3. Mouthing: Open and close mouth in pace with metronome 4. Talk Aloud: Talk strategies aloud	<u>Measurement</u> 1. Recruitment of inner speech to service executive control is suggested by presence and extent of performance costs (i.e., response time) in response to articulatory suppression. 2. In the talk-aloud condition a systematic analysis of transcripts was used to measure (a) speech rate (i.e., words per minute) and (b) utterance length (i.e., mean length of utterance in words).	○ In baseline there was no significant performance difference between groups although children with ASD did show a trend for more perseverative errors. ○ Children with ASD do not show a significant difference across conditions that aim to manipulate SDS use (i.e., articulatory suppression, talk-aloud). ○ TD children display a significant performance cost in the articulatory suppression condition (inhibits SDS) and a significant positive effect in the talk-aloud condition (encourages overt SDS). ○ In the talk aloud condition, there was a trend for TD children to use more words per minute than children with ASD. ○ Researchers suggest that children with ASD do not use inner speech to the same extent as TD children and there is no evidence that they benefit from verbalization of strategies.

Note. ASD = Autism Spectrum Disorder; TD = Typically Developing; ADHD: Attention Deficit Hyperactivity Disorder; SDS = Self-Directed Speech; V IQ = Verbal IQ; NV IQ = Non-verbal IQ; VMA = Verbal Mental Age; (n) = Number; (M) = Mean; Age: Year;Month.
Mixed Methods Appraisal Tool (MMAT) Rating (Pace et al., 2011): * = 1; ** = 2; *** = 3; **** = 4

Table S4

Research on Self-Directed Speech in Children with Attention Deficit Hyperactivity Disorder

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Copeland (1979) ***	Hyperactive (n=16) Age (M): 8;6 Gender: Male Conners Rating Scale (Teacher) Score (M): +2.08 TD (n=16) Age (M): 8;4 Gender: Male Conners Rating Scale (Teacher) Score (M): +0.90	Individual free play task o Novel playroom with 4 age appropriate games o Children play for 3 minutes alone	<u>Coding</u> Verbalization (all private speech due to task structure) during play was coded according to 9 pre-defined categories as per Kohlberg Yaeger, and Hjertholm (1968) <u>Measurement</u> 1. Frequency of private speech production 2. Frequency of private speech category as per Kohlberg and colleagues' (1968) 9 categories	o Group difference for frequency of private speech as hyperactive boys used significantly more private speech than controls. o Hyperactive boys used exclamations and descriptions of environment significantly more than the control group and more than all other categories. Hyperactive boys also made significantly more descriptions of self than planning statements. Researchers suggest that this reflects less mature use of statements. o The control group did not use any category significantly more than another.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Berk & Potts (1991) ****	ADHD (n=19); Medicated (n=14) and Non-medicated (n=5) Age (range): 6-12years Gender: Male IQ: >85 Receptive Vocabulary (M): 100.6 TD (n=19) Age (range): 6-12years Gender: Male IQ: >85 Receptive Vocabulary (M): 100.8	Independent completion of seated math task within the naturalistic classroom context o Each child works alone and independently during task o Teacher remains at a distance o Each child observed 4 times	<u>Coding</u> Behaviors were observed and coded as events during 10-second intervals and recorded in 20-second intervals. Trained observers coded private speech, motor accompaniment to task and attention levels. Private speech coded according to relevance and degree of internalization using 3 levels as per Berk (1986) <u>Measurement</u> Frequency in occurrence (%) of subtypes of private speech, motor activity and attention level	o Children with ADHD used significantly more overt task relevant private speech (Level 2) and less partially internalized private speech (Level 3) than age-matched controls. o Group differences reflect delayed internalization of SDS in ADHD group compared to TD controls, suggesting less mature use of SDS. o Overt task irrelevant (Level 1) private speech was positively correlated with diversion from the seatwork task, while partially internalized private speech (Level 3) was positively correlated with focused attention. o Analysis of 8 boys with ADHD on and off medication suggests medication use was associated with increased internalization of SDS.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Winsler (1998) ****	ADHD (n=19) - Medicated (n=9 but in 'washout' periods for experimental tasks) Age (M): 7;3 Gender: Male Receptive Vocab (M): 52.3rd percentile TD (n=20) Age (M): 7;3 Gender: Male Receptive Vocab (M): 66.8th percentile	Problem solving task completed in parent-child dyad and independently o Participants complete one of two problem solving tasks (i.e., Lego construction task or selective attention task – as determined by counter balanced random assignment) o Children initially work on task with parents o Children complete a similar version of the task alone	<u>Coding</u> A number of aspects of behavior and speech were considered: Parental utterances were coded according to 4 composite variables including: (a) Negative control (b) Positive teaching (c) Task regulation (d) Person regulation, as per Diaz and colleagues (1991; 1992) Child speech utterances in parent-child dyad were coded as: (a) Social speech (b) Independent verbalizations (c) Private speech as per Diaz, Neal and Amaya-Williams (1990) All child utterances were coded according to: (a) Addressee: social or private (b) Relevance and degree of internalization using 3 levels as per Berk (1986) (c) Content using categories adapted from Diaz, Winsler, Atencio and Harbers (1992)	o Age was positively correlated to task performance. o Receptive vocabulary ability was positively correlated with child internalized private speech, on-task attention and quality of parental scaffolding. o Parental scaffolding, withdrawal of control and negative control were significantly related to later task performance. o Parents of children with ADHD talked more and displayed poorer scaffolding during collaboration than parents of TD children. o Children with ADHD were more off-task and non-compliant than TD children. o When controlling for age and language ability there was no significant difference in social speech use and both groups used more overt private speech in the more difficult Lego construction task. o Children with ADHD used more task irrelevant private speech (Level 1). o Children with ADHD displayed less mature SDS in that they use proportionately more overt task

		(d) Speech fragmentation: complete or fragmented, as per Feigenbaum (1992) <u>Measurement</u> 1. Frequency of parental speech (i.e., total utterances per minute) 2. Frequency of parental speech categories (i.e., scaffolding) 3. Frequency of child private or social speech (i.e., total utterances per minute during collaboration) 4. Developmental level of private speech as determined by frequency of each level as per Berk (1986) 5. Frequency of private speech that is fragmented 6. Mean length of utterance 7. Frequency of functional content categories	relevant private speech while TD children use proportionately more partially internalized (Level 3) and abbreviated private speech.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Lawrence, Houghton, Tannock, Douglas, Durkin & Whiting (2001) ****	ADHD (n=57) Combined Subtype (n=37) and Inattentive Subtype (n=20) Age (M): 9;7 Gender: Male NV IQ (M): 114.5 V IQ (M): 105.8 TD (n=57) Age (M): 9;7 Gender: Male NV IQ (M): 115.4 V IQ (M): 102.2	Numerous behaviors were considered across video-game play and trip to the zoo. Private speech was recorded during one video-game. o Private speech was considered while children played an adventure game (i.e., Crash Bandicoot™) on a Playstation o Experimental conditions were manipulated by the presence or absence of a distractor (i.e., popular TV show presented simultaneously)	<u>Coding</u> In accordance with Barkley's (1997) model of ADHD, event related actions that represent behavior inhibition, four dependent executive functions (i.e., non-verbal working memory, verbal working memory/SDS, self-regulation of motivation and reconstitution), and motor control were coded during videogame play. Private speech was coded as (a) task-relevant self-directed utterances and (b) task-relevant affect expressions <u>Measurement</u> Number of self-directed on-task verbalizations and vocalizations	o Group differences during the video-game task suggest delayed internalization of SDS in the ADHD group as indicated by the significantly greater proportion of overt private use. This significant group difference did not persist in the presence of the distractor (i.e., popular TV show presented simultaneously). o Group differences in the use of overt private speech were no longer consistent when co-varying verbal IQ and age.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Kopecky, Chang, Klorman, Thatcher & Borgstedt (2005) ****	ADHD Inattentive subtype (n=19) Age (M): 9;6 Gender: Male (n=12) and Female (n=7) IQ (M): 108.93 ADHD Combined subtype (n= 22) Age (M): 8;9 Gender: Male (n=9) and Female (n=13) IQ (M): 106.56 TD (n= 34) Age (M): 9;2 Gender: Male (n=18) and Female (n=16) IQ (M): 121.35	○ Participants were assigned to medicated or placebo conditions in a randomly ordered double blind clinical drug trial ○ Performance and private speech use on the Tower of Hanoi task was recorded across three sessions	<u>Coding</u> (a) Only overt private speech utterances during Tower of Hanoi were coded as self-regulatory or not-self-regulatory (b) Self-regulatory utterances were categorized as defining, planning, monitoring and evaluating <u>Measurement</u> 1. Frequency of overt private speech utterances 2. Frequency of self-regulatory private speech utterances 3. Frequency of non-self-regulatory private speech utterances	○ All groups used more private speech when failing than succeeding but this was less significant for the TD group than either of the ADHD groups. ○ Overall there was a higher frequency of self-regulatory than not self-regulatory private speech. ○ Overt private speech was less frequent under the medication condition for both ADHD groups. ○ The effect of medication on a reduced rate of self-regulatory speech under failure was small for the inattentive group, who appear to display a practice effect but significant in the combined group. ○ Not self-regulatory speech increased under failure and attenuated in response to medication for both ADHD groups.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Winsler, Abar, Feder, Schunn & Rubio (2007) **** NOTE: This study is also included in the ASD section.	ADHD (n=21) Age (M): 11;7 Gender: Male (n=13) and Female (n=8) ASD (n=33) Age (M): 11 Gender: Male (n=32) and Female (n=1) TD (n=28) Age (M): 10;4 Gender: Male (n=19) and Female (n=9)	Performance and private speech use are considered across two computer administered tasks of executive functioning (i.e., Wisconsin Card Sorting Task and the Building Sticks Task)	<u>Coding</u> All child speech utterances were coded according to: (a) Addressee: social or private (b) Relevance and degree of internalization using 3 levels as per Berk (1986) <u>Measurement</u> 1. Frequency of social speech per minute 2. Frequency of private speech per minute 3. Frequency of Berk's (1986) categories per minute 4. Proportion of private speech in each of Berk's (1986) categories	o Children with ASD and ADHD experience significantly greater challenge with executive functioning compared to TD controls as indicated on measures of the BRIEF (Gioia et. al., 2000) and task performance. o The majority of children used private speeech within executive functioning tasks with no significant group differences. o When all children made errors within the Building Sticks task they were more likely to use private speech. o Children with ADHD showed significantly greater amounts of irrelevant overt private speech per minute than the TD or ASD group. o On the Card Sorting Task children with ADHD and ASD used proportionately more overt and less partially internalized private speech than TD controls.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Corkum, Humphries, Mullane & Theriault (2008) ****	ADHD Combined subtype (n= 16) Age (M): 8;10 Gender: Male (n=15) and Female (n=1) Estimated IQ (M): 98.19 TD (n= 16) Age (M): 9;4 Gender: Male (n=13) and Female (n=3) Estimated IQ (M): 111.25	A problem-solving task (Object Assembly and Picture Arrangement) from the WISC-III (Weschler, 1991), and inhibition and sustained attention task, the Conners' Continuous Performance Task II (Conners, 2000)	<u>Coding</u> All child speech utterances were coded according to: (a) Addressee: social, private, or not codable in nature (b) Relevance and degree of internalization using 3 levels as per Berk (1986) <u>Measurement</u> 1. Frequency of private speech production 2. Frequency of Berk's (1986) private speech categories per task	○ The amount of private speech use was not related to Vocabulary subtest score on the WISC-III ○ On the problem-solving task children with ADHD used significantly more task irrelevant and task relevant overt private speech than the TD group with no group difference evident in partially internalized private speech use. ○ On the inhibition and sustained attention task children with ADHD used significantly more task-relevant overt and partially internalized private speech than the TD group.

Study & MMAT	Sample	Task/s	SDS Coding and Measurement	Key Findings
Reck, Hund & Landau (2010) ****	ADHD Combined subtype (n= 17) Age (M): 10;2 Gender: Male IQ: 97.47 TD (n= 21) Age (M): 10;9 Gender: Male IQ: 115.71	Object location memory task: o A box containing 20 locations and 20 objects used to learn locations o 30-50 minute sessions divided into a learning and test phase o Participants learn the locations of 20 objects o Learning trials continue until participants can correctly place all objects, following which the test phase begins	<u>Coding</u> Attention to task, learning errors, memory errors and private speech were coded. Private speech was coded as an event during learning and testing phases in alternating 10-second intervals. Private speech events were coded according to: (a) Relevance and degree of internalization using 3 levels as per Berk (1986) <u>Measurement</u> Proportional use of each category by dividing the number of private speech events per category by total private speech events	o When provided with a sufficient number of trials to learn the task, children with ADHD were comparable to TD controls on object location memory, however they made twice as many errors while learning object locations. o During the learning phase, children with ADHD showed significantly less attention to task, more errors, and more private speech than TD controls. o During the learning phase, children with ADHD displayed significantly more task irrelevant and task relevant private speech than TD controls. o For TD children, attention to task was significantly associated with task-relevant overt private speech. For children with ADHD both task-relevant overt and partially internalized private speech was inversely related to attention to task.

Note. ADHD: Attention Deficit Hyperactivity Disorder; TD = Typically Developing; ASD= Autism Spectrum Disorder; SDS = Self-Directed Speech; V IQ = Verbal IQ; NV IQ = Non-verbal IQ; VMA = Verbal Mental Age; (n) = Number; (M) = Mean; Age: Year;Month.
Mixed Methods Appraisal Tool (MMAT) Rating (Pace et al., 2011): * = 1; ** = 2; *** = 3; **** = 4

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