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MEMORY IN AUTISM SPECTRUM DISORDER: A META-ANALYSIS OF EXPERIMENTAL STUDIES.

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Corresponding Author:	Bérengère Guillery-Girard INSERM-EPHE-Caen University FRANCE
Corresponding Author E-Mail:	berengere.guillery-girard@ephe.psl.eu
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	INSERM-EPHE-Caen University
Other Authors:	Pierre Desaunay
	Anaïs R. Briant
	Dermot M. Bowler
	Melanie Ring
	Priscille Gérardin
	Jean-Marc Baleyte
	Fabian Guénolé
	Francis Eustache
	Jean-Jacques Parienti
Corresponding Author's Secondary Institution:	

Title page with All Author Information

MEMORY IN AUTISM SPECTRUM DISORDER: A META-ANALYSIS OF EXPERIMENTAL STUDIES.

P. Desaunay[1,2], AR. Briant[3], D. M. Bowler[4], M. Ring[3,5], P. Gérardin[6], JM. Baleyte[1,7], F. Guénolé[1,2], F. Eustache[1], JJ. Parienti [3,8], B. Guillery-Girard[1]

1 Neuropsychologie et Imagerie de la Mémoire Humaine, Normandie Université, UNICAEN, PSL Université Paris, EPHE, INSERM, U1077, CHU de Caen, Caen, France

2 Service de Psychiatrie de l'enfant et de l'adolescent, CHU de Caen, Caen, France

3 Department of Biostatistics and Clinical Research, CHU de Caen, France

4 Autism Research Group, Department of Psychology, City, University of London, London, United Kingdom

5 Department of Child and Adolescent Psychiatry, University Hospital Carl Gustav Carus, Technische Universität Dresden, Germany

6 Fédération Hospitalo-Universitaire de Psychiatrie de l'Enfant et de l'Adolescent (FHUPEA), CHU de Rouen, France

7 Service de Psychiatrie de l'enfant et de l'adolescent, Université Paris Est Créteil, Hôpital Intercommunal de Créteil, Créteil, France

8 EA2656 Groupe de Recherche sur l'Adaptation Microbienne (GRAM 2.0), Université Caen Normandie, Caen, France

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ABSTRACT

To address inconsistencies in the literature on memory in Autism Spectrum Disorder (ASD), we report the first ever meta-analysis of short-term (STM) and episodic long-term (LTM) memory in ASD, evaluating the effects of type of material, type of retrieval and the role of inter-item relations.

Analysis of 64 studies comparing individuals with ASD and typical development (TD) showed greater difficulties in ASD compared to TD individuals in STM (Hedges' g=-0.53 [95%CI -0.90; -0.16], *p*=.005, I^2=96%) compared to LTM (g=-0.30 [95%CI -0.42; -0.17], *p*<.00001, I^2=24%), a small difficulty in verbal LTM (g=-0.21, *p*=.01), contrasting with a medium difficulty for visual LTM (g= -0.41, *p*=.0002) in ASD compared to TD individuals. We also found a general diminution in free recall compared to cued recall and recognition (LTM, free recall: g=-0.38, *p*<.00001, cued recall: g=-0.08, *p*=.58, recognition: g=-0.15, *p*=.16; STM, free recall: g=-0.59, *p*=.004, recognition: g=-0.33, *p*=.07).

We discuss these results in terms of their relation to semantic memory. The limited diminution in verbal LTM and preserved overall recognition and cued recall (supported retrieval) may result from a greater overlap of these tasks with semantic long-term representations which are overall preserved in ASD. By contrast, difficulties in STM or free recall may result from less overlap with the semantic system or may involve additional cognitive operations and executive demands. These findings highlight the need to support STM functioning in ASD and acknowledge the potential benefit of using verbal materials at encoding and broader forms of memory support at retrieval to enhance performance.

KEYWORDS

Autism spectrum disorders, short-term memory, long-term memory, episodic memory, meta-analysis.

PUBLIC SIGNIFICANCE STATEMENT

The results of this meta-analysis indicate global difficulties in memory in ASD, with short-term (STM) being more affected than episodic long-term memory (LTM). We found verbal LTM to be relatively preserved, which contrasts with LTM difficulties for visual material. For both STM and LTM, we found a general reduction in free recall compared to cued recall and recognition, arguing in favor of using memory support in rehabilitation.

INTRODUCTION

For over seven decades, clinicians and scientists have noted specific and sometimes contradictory features of memory in autism. In 1943, Kanner observed that “the children’s memory was phenomenal” (p. 245), and was fascinated by the heterogeneity of their memory abilities “the excellent memory for events of several years before, the phenomenal rote memory for poems and names and the precise recollection of complex patterns and sequences”(p. 247). By contrast, Boucher & Warrington (1976) used experimental data showing diminished recall for pictures and words to draw parallels between autism and the amnesic syndrome. In a similar vein, Hermelin & O’Connor (1970) identified difficulties in using semantic relatedness to facilitate memory. These experimental studies also reveal that people with ASD are characterized by a degree of heterogeneity in their memory functioning. Memory for general knowledge, such as poems, seems excellent (Ben Shalom, 2003), in contrast with a diminished capacity to encode memories for personally experienced events that occurred only once, such as learning a list of items that refers to episodic memory (Lind, 2010). The episodic memory system consists of specific memories of personally-experienced events, situated in the temporal and spatial contexts of their acquisition. Episodic memory also enables the retrieval of associations between items and is associated with autonoetic conscious awareness (recollection, associated with remembering) (Tulving, 1972; Eustache *et al.*, 2016). Studies on memory have been conducted on a range of ASD populations using different methodologies, stimulus materials and types of processing and although there have been comprehensive reviews of the area (e.g. Boucher & Bowler, 2008; Boucher, Mayes, & Bigham, 2012), no systematic meta-analysis of these studies to determine effect sizes has yet been conducted. It is at this gap in the literature that the present study is aimed. To orient the reader and to underpin the need for the proposed meta-analysis, we start with an overview of the main findings and controversies in studies of episodic long-term memory in ASD. We included short-term memory (STM) in this meta-analysis because as it shares the same stages of encoding and retrieval with long-term memory (LTM), we need to consider its functioning when interpreting the patterning observed in episodic memory.

Memory is a complex set of cognitive functions that has been thought of as comprising different, often multi-component systems. One such system is that of Atkinson & Shiffrin (1971), which distinguishes between STM and LTM, mainly based on different capacities of storage relying on distinct processes. For STM, storage is maintained by rehearsal of a limited quantity of information (reviewed by Norris, 2017). By contrast, LTM can contain unlimited quantities of information held for durations that can extend to decades. The STM concept has been extended further by Baddeley's (2000) model of working memory (WM), which emphasizes the manipulation of information during cognitive tasks. This model encompasses two modality-specific short-term stores (visuospatial and phonological) that depend on a central executive, which enables the active processing of information. In memory studies in ASD, the distinction between STM and WM tests is rarely drawn, and only a few studies have focused on STM exclusively. LTM can also be divided into different sub-systems. The first includes explicit and implicit memory (Cohen & Squire, 1980). Explicit, or declarative memory, refers to verbalizable information, accessible to awareness and contrasts with implicit and procedural memory which are both dedicated to actions and processes that take place without conscious awareness. A recent meta-analysis has concluded that implicit learning is preserved in ASD (Foti *et al.*, 2015). A second distinction focuses on semantic and episodic memory (Tulving, 1972). Semantic memory stores general, factual knowledge and is associated with noetic conscious awareness (Tulving, 1986) yielding a sense of familiarity which is associated to knowing (for reviews, see Yonelinas, 2002; Diana, Yonelinas, & Ranganath, 2007).

Studying STM is of interest in typical and atypical development, since STM provides a link between perception and cognition (Baddeley, 2003a). Several investigations have identified that STM correlates with the acquisition of higher-order abilities and functioning in typical development, such as vocabulary and grammar (Verhagen & Leseman, 2016), high-order visual attention (Astle & Scerif, 2011) and cognition (Potter, 2012). Similar results have been found in neurodevelopmental disorders (Gathercole *et al.*, 2005; Gathercole & Alloway, 2006; Majerus *et al.*, 2007). In adults with ASD, Poirier *et al.* (2011) identified preserved verbal short-term item memory, but diminished short-term order recall and recognition. Subsequently, Bowler *et al.* (2016) replicated this result with visuospatial material, hypothesizing that diminished short-term processing of the temporal sequence of the items may be at the core of STM difficulties in ASD. Other recent findings concluded to a dissociated pattern in STM with impaired visuospatial STM and preserved verbal STM. Visuospatial deficits seem to differentiate ASD from other developmental disorders (Alloway, Seed, & Tewolde, 2016), and may be a specific marker of ASD in adolescence (Chen *et al.*, 2016). These results contrast with superior verbal STM that has been described in adults with ASD without a history of speech onset delay. In these individuals, verbal STM was associated with their higher vocabulary knowledge (Chiodo, Mottron, & Majerus, 2019). Regarding the type of retrieval, neither STM nor WM studies have yet compared recall and recognition (see Kercood *et al.*, 2014 for review), thus necessitating their comparison in this meta-analysis.

In spite of this potential interest, the specific study of STM in ASD has received relatively little consideration. Instead, most studies have used WM tasks that emphasize short-term maintenance with controlled manipulation of information by the central executive (Baddeley, 1996). In their review, Barendse *et al.* (2013) identified a dissociation between impaired visuospatial WM and intact verbal WM in ASD, similarly to STM (Williams, Goldstein, & Minshew, 2005; 2006b; Cui *et al.*, 2010). A subsequent meta-analysis conducted by Wang *et al.* (2017) also found visuo-spatial WM to be more impaired than verbal WM, and did not demonstrate further impairment on WM tasks that included maintenance plus manipulation compared to maintenance only (i.e. STM). Beyond these results, we can discuss tasks used to test either STM or WM. In Wang *et al.*'s (2017) study, some of the selected WM tasks involving manipulation were N-back and backward span tasks, which may not fully reflect the manipulation by the central executive theorized by Baddeley (1996). Wager & Smith (2003) notably considered N-back tasks as involving continuous updating of the to-be-memorized information, but not manipulation, and more recent studies have confirmed this account (e.g. Rac-Lubashevsky & Kessler, 2016a; Rac-Lubashevsky & Kessler, 2016b). Moreover, Colom *et al.* (2007) identified overlapping brain areas subserving backward and forward tasks, preventing any clear classification of backward tasks as specifically being WM. St Clair-Thompson (2010), comparing backward digit recall tasks to different STM and WM tasks, concluded that backward tasks are a measure of STM in typical adults, and Poirier *et al.* (2011) classified backward recall this way in a STM study in ASD. More recently, comparing forward and backward verbal and visuospatial tasks, Norris, Hall, & Gathercole (2019) hypothesized backward recall to be a form of STM associated with other cognitive operations with inter-individual strategies. In a more recent meta-analysis of WM in ASD, Habib *et al.* (2019) did not replicate Wang *et al.* (2017)'s findings, by not identifying any significant difference between visuospatial and phonological WM impairments. Instead, they found a similar moderate effect size for both WM domains, larger than Wang et al (2017)'s results, suggesting a global impairment of WM in ASD, independent of the specific modality of the task. Manipulation observed in WM tasks depends on several different executive functions (Baddeley, 2002), and two recent meta-analyses have confirmed an overall impairment of executive functions in ASD (Demetriou *et al.*, 2018; Lai *et al.*, 2017), in line with the executive dysfunction hypothesis (Ozonoff, Pennington, & Rogers, 1991; Russell, 1997), which prevents any conclusions about short-term storage (i.e. STM), in ASD.

STM and LTM are closely associated (see Eriksson *et al.*, 2015; Norris, 2017). First, encoding in short-term is thought to be supported by the temporary reactivation of LTM representations as proposed by Cowan (2008) and second, encoding information into episodic LTM involves recruitment of STM. That is the reason why we were interested in comparing STM and LTM functioning in ASD. Focusing on episodic LTM, some authors concluded that the enhanced egocentric visuospatial memory in ASD may be related to perceptual processes and specific top-down mechanisms (Ring *et al.*, 2017; 2018). In addition, Caron *et al.* (2004; 2006) identified superior performance for visuospatial material in adolescents and adults with ASD compared to typically developing (TD) controls. Enhanced detection and enhanced memory for simple visuospatial patterns would favor better discrimination of more complex patterns that may share common perceptual properties (e.g. maps, landscapes,…), which could in turn explain the visuospatial peaks of abilities reported in some autistic individuals (Roser *et al.*, 2015). Other accounts have suggested alterations in encoding-related processes. Authors such as

Bowler *et al.* (1997) and Tager-Flusberg (1991) have argued for a tendency to draw less benefit from the semantic aspects of the to-be-remembered material, possibly because of a diminished detection of higher-order semantic features of stimuli. For instance, when varying the level-of-processing during the encoding of Japanese characters, semantic processing does not foster memory in participants with Asperger syndrome compared to a graphemic or phonemic encoding, as it does in typical individuals (Toichi & Kamio, 2002). In the same way, people with ASD did not detect common similarities between related words, leading to an absence of enhanced cued recall performance (Mottron *et al.*, 2001). Close to these findings, Smith *et al.* (2007) and Meyer *et al.* (2014) concluded that there was an elaborative encoding deficit in memory and learning in ASD, whatever the nature of the relations among learned items. Smith *et al.* (2007) manipulated semantic or phonological similarity in their word list and showed that adults with Asperger syndrome were unable to benefit from inter-item semantic or phonological relations to foster memory, contrary to TD individuals. In addition, Meyer *et al.* (2014) used either to-be-learned or to-be-forgotten word lists and identified lower recognition and remembering performances for the to-be-learned words in adults with ASD compared to controls, suggesting that participants with ASD were less engaged in elaborative rehearsal, leading to diminished encoding and learning. Most of the conclusions about episodic encoding have been interpreted in conjunction with the *weak central coherence* and *enhanced perceptual functioning* theories in ASD, which respectively define a spontaneous tendency to process the local dimension of a stimulus to the detriment of its global dimension (Happé, 1996; Happé & Frith, 2006), and an enhanced locally-oriented processing, especially in visual and auditory domains (Mottron *et al.*, 2001; 2006).

Studies of episodic retrieval have consistently identified diminished recollection processes in ASD, which may contribute to lower levels of the kind of recall that relies on recollection (Bowler, Gardiner, & Gaigg, 2007), source memory (Lind & Bowler, 2009) and associative memory (Gaigg *et al.*, 2015). Bowler *et al.* (2007) manipulated encoding factors that affect the subsequent degree of awareness at test and identified the same pattern of results for recollection and familiarity responses in participants with ASD and controls, suggesting that recollection is quantitatively diminished but qualitatively similar to TD people. By contrast, studies have demonstrated an unimpaired familiarity processes implicated in recognition-based retrieval and may lead to its relative preservation in ASD (e.g. Bowler *et al.*, 2007, 2015; Grainger *et al.*, 2017). Electrophysiological studies suggest that recollection and familiarity processes may share a single non-differentiated episodic memory system in adults with ASD contrary to the dual-system memory in typical individuals (Massand *et al.*, 2013; Massand & Bowler, 2015). However, recent findings have challenged this familiarity/recollection dissociation in ASD, showing diminished item memory with altered familiarity, while spared relational memory and recollection, suggesting primarily an impairment in familiarity process (Solomon *et al.*, 2016). More recently, Cooper *et al.* (2017) showed that eye movements at encoding predict subsequent recognition and recollection for visual scenes in typical adults only, and by contrast identified that recollection in adults with ASD was associated with lower similarity between encoding- and retrieval-related eye movements, suggesting a disruption between the encoding and recognition phases.

Broader difficulties are observed in the organization of the to-be-memorized information in ASD. Renner *et al.* (2000) did not observe the primacy and recency effects during the retrieval of a list of unrelated words and Bowler *et al.*'s (2008) participants showed an idiosyncratic organization of retrieved words. When ASD participants were asked to learn semantically related words, they clustered words into fewer categories at recall. Bowler, Gaigg, & Gardiner (2010) have interpreted many of the foregoing findings using the *task support hypothesis* (TSH), which postulates that in situations providing support for the processing of relational information, individuals with autism can employ such processes effectively (Bowler *et al.*, 1997, 2004; Gaigg *et al.*, 2008). This account leads us to suppose that memory difficulties with associative information are more related to organization at both encoding (Bowler *et al.*, 2008; Southwick *et al.*, 2011) and retrieval (Bowler *et al.*, 2004) rather than at the encoding stage *per se*. As a consequence, providing an organizational framework for the to-be-memorized information, such as hierarchically embedded categories for instance, enhances memory performance as was demonstrated by Bowler *et al.* (2009). Likewise, support procedures that focus on the retrieval stage, such as cued recall and recognition with semantic material, enhances memory in autistic individuals to a comparable level to that seen in comparison participants (Bowler *et al.*, 1997; 2000; 2008; Mottron *et al.*, 2001; Tager-Flusberg, 1991). Furthermore, the TSH is not limited to semantically related conditions, but may be adapted to unrelated conditions (Bowler *et al.*, 2000, 2008, 2015; Ring *et al.*, 2015).

Independently of memory stages, Williams *et al.* (2006), postulated that the core of memory difficulties in autism is a disorder in *processing complex information*, which gives rise to difficulties when demands for integration of information increases. In this context, a growing interest in relational memory in autism has progressively emerged. To explain why individuals with ASD experience more difficulties in some tasks involving relational processing than others, the *relational binding account* (Bowler *et al.*, 2011; Gaigg *et al.*, 2008) suggests a specific impairment in hippocampally mediated relational and contextual memory, while item-specific and context-independent memory remain intact. This theory is related to Halford's (1993) *taxonomy of cognitive development*, which describes the cognitive development in stages of increasing complexity, from unary relations (the processing of individual items) to binary relations (the processing of pairs of items), ternary relations (the processing of triplets) and so on. Bowler *et al.* (2011) suggested that memory difficulties in ASD would arise from problems with binary and ternary relations, the latter being associated to other cognitive difficulties such as joint attention, which requires to see the relations among self, another person, and an object. A binding deficit may explain other cognitive theories in ASD such as the theory of the *processing of complex information* (Williams, Goldstein, & Minshew, 2006a), suggesting that difficulties arise when demand for integration of information increases (Bowler, Gaigg, & Gardiner, 2014), or *weak central coherence* theory (Happé & Frith, 2006), since a relational deficit may lead to difficulties in binding together the elements of a scene into a coherent representation (Lind, Bowler, & Raber, 2014). Reduced relational memory in ASD compared to TD people has been reported in various paradigms (see Souchay *et al.*, 2013 in adolescents, Bowler *et al.*, 2014 in adults), other findings tend to show improved performance from childhood to adulthood (Ring *et al.*, 2016; Solomon *et al.*, 2016), but no decrease between younger and older individuals with ASD contrary to the pattern seen in healthy ageing individuals with typical development (Bowler *et al.*, 2007; 2014). Diminished relational memory has been related to neuroanatomical models suggesting primary hippocampal impairments (Gaigg *et al.*, 2008), and cognitive models associating relational memory with executive dysfunction (Maister *et al.*, 2013), and top-down deficits leading to an effortful and less automatic associative retrieval (Loth *et al.*, 2011). Although supported by a large body of literature, the relational binding account has been challenged recently by Cooper *et al.* (2015) and Ring *et al.* (2016), whose findings show similar levels of autism-related difficulty in both item and relational memory with visual material. Hence, the present meta-analysis may shed a new light on these differences.

To summarise, the present meta-analysis focuses first on STM and then on episodic memory. For STM, we address the following objectives: (1) to determine whether or not the active, rehearsal-based storage that mainly differentiates STM and LTM is diminished in ASD; (2) to confirm the dissociation between impaired visuospatial STM and preserved verbal STM in ASD; (3) to evaluate the effect of type of retrieval (i.e. free or cued recall, and recognition) on STM performance; and (4) to confirm the large reduction in STM order recall in ASD by comparing the presence and absence of the requirement to engage in serial recall. For episodic memory in ASD, we have the following four aims: (5) given the close relationship between STM and episodic LTM, to evaluate whether episodic memory is as impaired as is STM in ASD; (6) given the discrepancies in the experimental work reviewed above, to determine whether visuospatial LTM performance is superior to that of verbal LTM; (7) to confirm that supported retrieval procedures (i.e. cued recall and recognition) yield better performance than unsupported procedures such as recall; (8) to determine whether associative memory is more adversely altered than item-memory as suggested by the hippocampal relational deficit account and whether individuals with ASD differ from individuals without ASD in benefitting less from semantic relatedness among studied items.

To address these objectives, we conducted a systematic review and meta-analysis. First, we analyzed STM and LTM separately. Second, we then evaluated the type of material at encoding (i.e. verbal, visual, and visuospatial) and the type of retrieval (i.e. free and cued recall, recognition) together and according to the type of material studied. Finally, we evaluated the effect of the organization of material, focusing on serial STM, and associative or semantically related LTM.

MATERIALS AND METHODS

This study has adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA, Moher *et al.*, 2009). The protocol of this review was prospectively registered in the International Prospective Register of Systematic Reviews, PROSPERO (CRD42018088958).

1. Selection criteria and Search strategy

1.1. Study selection

We selected studies with the following inclusion criteria:

1. Studies comparing individuals with ASD and those with TD published in English and in peer-reviewed journals.

2. Clinical diagnosis of ASD or Asperger syndrome confirmed by the ADI or ADI-R, and/or ADOS or ADOS-2 method for diagnosis, and/or DSM-IV, DSM-V, or ICD-10 diagnostic criteria. The diagnosis must have been made on all participants.

3. Groups with ASD had to be compared to TD groups with normal IQ (evaluated with Wechsler or K-Bit scales).

4. Studies reporting memory performance in verbal, visual, visuospatial domains, and measuring immediate recall, delayed recall, immediate recognition and delayed recognition.

5. Studies that enabled the calculation of effect sizes by inclusion of means and standard deviations.

Exclusion criteria were:

1. To limit between-study heterogeneity, we did not include:
   1.1. studies that employed DSM-III diagnostic criteria, similar to the Baixauli *et al.* (2016) meta-analysis, because ASD participants with DSM-III criteria have electrophysiological differences compared to those who meet DSM-IV criteria (Cui *et al.*, 2017)
   1.2. studies with pervasive developmental disorders-not otherwise specified (PDD-NOS), since specific difficulties are reported in executive functions (Schurink *et al.*, 2012), working memory (de Bruin, Verheij, & Ferdinand, 2006) and episodic memory (Koyama & Kurita, 2008) in individuals with PDD-NOS, that have not been yet compared with ASD. Hence, we cannot conclude that individuals with ASD and PDD-NOS share the same cognitive difficulties. Moreover, many studies that use DSM-IV criteria excluded PDD-NOS.
2. Exclusion of studies with different methodologies:
   2.1. studies explicitly investigating memory for material that was not presented in the experiment, such as autobiographical memory tasks, tests of incidentally-encoded material such as source memory tests (but performance for any item retrieval reported in such studies was included)
   2.2. prospective memory, because a meta-analysis had already been performed (Landsiedel *et al.*, 2017).
   2.3. retrieval after very long delays (hours, or days) because these tests implicate a significant part of consolidation effects
   2.4. auditory stimuli and memory for perceptual details, because of high methodological heterogeneity across studies
   2.5. low-frequency words (because of scarcity effect in TD individuals), pseudo-words as stimuli and false recognition memory tasks
   2.6. memory for faces, for their social properties

1.2. Search strategy.

A literature search was conducted to identify published studies in which STM or LTM has been tested in individuals with ASD. This was performed in PubMed and ScienceDirect. Keywords used, for the research, were both MeSH (Medical Subject Heading) and text word terms related to ASD and memory and they were associated with Boolean terms. Different combinations were performed to optimize the literature search, the one that identified the largest number of studies being: ("autistic disorder" OR "autism spectrum disorder" OR "autism") AND memory. A literature search was conducted on January 12, 2018, updated on June 1st, 2019. Relevant articles were also retrieved from the reference lists of included studies or were found by hand search.

2. <u>Data-Extraction.</u>

The first author (PD) identified and screened titles and abstracts. Full-text reading for assessment of eligibility and data extraction were carried out independently in duplicate by the first and the last authors (PD, BG). For each study, we collected: 1) the title, name and country of the first author, 2) journal and year of publication, 3) abstract, 4) type of diagnoses 5) number of participants with or without autism, 6) number of male participants, 7) means and standard deviations of demographic variables (age in years, full scale intelligence quotient (IQ), verbal IQ/verbal comprehension index and performance IQ/perceptual reasoning index), 8) type of memory task, 9) nature of the encoded stimuli, 10) means and standard deviations of each group on the memory task, 11) medication and 12) manual laterality if specified. A verification of the extracted data was carried out by the first and the last author. Risk of bias analyses were also performed with regard to diagnostic validation (validation via ADI-R and ADOS vs validation via ADI-R or ADOS vs clinical observations only in reference to the DSM or ICD). Table 1 presents each of the included studies. Memory assessment details were extracted and categorized (see Figure 1).

3. Categorization of memory tests.

Supplementary Table 1 describes the domains used to categorize memory tasks. We aimed to examine: 1) STM and LTM and for each, 2) type of information encoded (verbal, visual, and visuospatial), 3) test used at retrieval (free recall, cued recall and recognition), 4) type of organization of the items to be memorized (associative, serial, and with semantic relatedness).

Following the meta-analyses of memory by Buck *et al.* (2013) and Roig *et al.* (2013), we distinguished between STM and LTM tests by adopting the classifications of Lezak *et al.* (2004) and Strauss *et al.* (2006). STM refers to the retention of small amounts of information (less than 10 items) over a relatively short period of time (from 1 or 2 seconds to about half a minute). Tests assessing STM are characterized by the immediate retrieval of memorized information. Because STM involves retention of information in a relatively unprocessed or interpreted form (Richardson, 2007), we also included backward and N-back tasks as STM tasks plus additional cognitive control. LTM refers to the retention of complex material or retention of information over a delay. We considered the following paradigms as LTM tasks: (1) participants were required to study at least 10 items between encoding and retrieval, or (2) a delay was present between encoding and retrieval, or (3) participants were required to encode different material (e.g. sentences, complex visual stimuli). Criteria 1 and 2 are similar to those of Montoya *et al.'s* (2006) meta-analysis on LTM in Huntington's disease.

We then categorized studies according to the type of information encoded: verbal (provided in auditory or visual modality), visual, and visuospatial (see figure 1). Verbal material included letters, numbers, and words (single words, word pairs or triplets, word lists, sentences). Visual material included concrete or abstract pictures and drawings.

Finally, we looked at tasks that required the memorization of information organized in a specific way, i.e. associative memory tasks, serial memory tasks, and tasks studying semantic relatedness between items, based on the tests identified in the included studies. For associative memory tasks, we referred to Ranganath's (2010) Binding Item – Context model of associative memory which focuses on item – item or item – context (i.e. spatial, temporal, etc.) binding. Serial memory tasks are characterized by the recovery of relational information between an item and its temporal or spatial order (Mizrak & Öztekin, 2016), which requires a controlled memory search, namely controlled retrieval (Öztekin *et al.*, 2009). Serial memory tasks consisted of STM tasks including retrieval of lists respecting the order of presentation (forward) and retrieval of sequences (e.g. Corsi block). Retrieval of lists irrespective of the order, and the Benton Visual Retention Test, were not considered as tests of serial recall (Verté *et al.*, 2005; Geurts *et al.*, 2004). Finally, we treated items (words or pictures) that belonged to the same semantic category as semantic association lists.

Insert Figure 1- Categorization of memory tests.

4. Quality assessment

The *Standard Quality Assessment Criteria for Evaluating Primary Research Papers* (Kmet, Lee, & Cook, 2004) was used to evaluate the quality of included studies. The checklist was used in its original form, though criteria 5 to 7 were removed as they related to interventional studies and were not relevant for this meta-analysis. All included studies were scored (2 = Yes, 1 = Partial, 0 = No) on 11 criteria, by the first and the last authors, with complete agreement. Assessment total scores were converted to a percentage score, that ranged from 81 to 100%. A total of 40 studies were evaluated as very good quality (scoring 22/22 = 100% and 21/22 = 95%), and a total of 14 studies were evaluated as good quality (scoring 20/22 = 91% and 19/22 = 86%, and 18/22 = 81%). All studies were considered of sufficient quality (see Supplementary Table 2).

5. Statistical Analysis.

For each comparison, articles were first examined to exclude possible duplication of data from the same participants across studies. The same sample was defined as a combination of same authors, same sample size, same baseline characteristics of the sample in two different publications (e.g. the same groups in longer follow-up). We excluded duplicate data in order to ensure that only samples that were independent across studies were included. Hence, we excluded studies with the lowest number of participants or the least number of tests. Sometimes, we identified two or more samples of participants in one study that were completely independent (for example, samples using different age groups), we analyzed each sample as an independent study. Many studies used several memory tasks resulting in more than one effect size being calculated. According to the objectives of each analysis, when several effect sizes were computed in one study, an unweighted average effect size was calculated and used.

In a first part of the analysis, we compared the performance of ASD participants with that of TD comparison participants. To estimate the difference between the two groups, we used Review Manager software (RevMan, Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) to compute effect sizes (Hedges' g) and their 95% confidence intervals based on the standardized mean difference weighted by the inverse of the variance. We used the standardized mean difference because our primary endpoint was quantitative and because the rating scales for each study were different. A *p*-value of 0.05 was used as a cut-off point in the z-test to determine the statistical significance of the overall effect size, which could then be interpreted according to Cohen's criteria (Cohen, 1988): g=0.2 was considered a 'small' effect size, 0.5 represented a 'medium' effect size and 0.8 a 'large' effect size. Negative effect sizes meant that the ASD group performed worse than the TD group. Heterogeneity of outcomes was determined using chi-squared (Q) and Higgins I^2 tests. For the chi-square test, we used a cut-off at $p < 0.05$. For the Higgins I^2 test, we considered $I^2 \geq 50\%$ to be indicative of substantial heterogeneity, and $I^2 \geq 75\%$ to be indicative of serious heterogeneity (Higgins & Thompson, 2002). For each comparison, we used a random effect model. Publication bias was examined by Egger's test (Sterne, Egger, & Smith, 2001), using SAS software version 9.4 (SAS institute).

With the same software, we carried out a linear regression analysis. To explain the heterogeneity of the effect size in some comparisons, we performed univariate analyses using the following moderator variables: age, IQ (FSIQ), and autistic score (ADOS). We did not use the DSM-IV or DSM-V criteria as factors, as only four studies used the DSM-V on 64 studies in total. We then used R software (version 3.4.4; The R Foundation for Statistical Computing) to generate figures to illustrate the results. If heterogeneity was significant, a sensitivity analysis was carried out in order to evaluate the robustness of our results when the most influential studies were excluded. We consider a p-value<0.05 to denote statistical significance.

RESULTS

1. Number of studies

We identified 5149 studies on January 12, 2018 (including 2012 in PUBMED and 3137 in SCIENCEDIRECT), and 1768 additional studies published between January 12, 2018 and June 1st, 2019 (including 306 in PUBMED and 1462 in SCIENCEDIRECT) (Figure 2). After removing duplicates, 6727 records remained for analyses. Based on a screen of the titles and abstracts, 6231 studies were excluded because they did not meet inclusion criteria. The remaining 496 were analyzed in more detail by going through the full text. Out of these studies, 132 studies were excluded because the memory task was other than specified, 115 were excluded because they did not specify at least FSIQ or they used different measures of IQ other than Wechsler's scales (WISC/WAIS) and K-BIT; 66 studies were excluded because including other patients than with ASD or Asperger syndrome; 48 studies were excluded because they did not permit the calculation of effect sizes, 40 studies were excluded because they did not use ADI and/or ADOS, and/or DSM-IV, DSM-V, or ICD-10 criteria for diagnosis for all ASD participants; 29 studies were excluded because they did not use a comparison group and 2 studies were excluded because the comparison group did not consist of TD individuals. This resulted in 64 articles being included in the meta-analysis. As explained earlier on, to avoid the risk of bias due to the repetition of some participants, it was necessary to exclude some studies that included the same group of participants on some comparisons. The exclusion of these studies depended on the comparison (for example: it was possible to find two studies with the same sample in the comparison in global LTM, then a choice must be made between the two; while one may have used free recall and the other the recognition and in this case, each will be found in these independent comparisons).

2. <u>Characteristics of the studies and the samples</u>

This analysis of 64 studies compared 2923 ASD and 2877 TD individuals. The most common diagnostic reference was DSM-IV and/or ICD-10 (75%). Only four studies used DSM-V and eleven studies used only ADOS and/or ADI as a diagnostic tool and one study used DSM-III or DSM-IV or ICD-10. Forty-five studies used at least ADI, ADOS or both to identify4 autism severity. Nineteen studies used only DSM and/or ICD-10 criteria without assessing autism severity.

The characteristics of the studies are presented in Table 1. Each of the tasks in the 64 studies finally included was classified under several headings. The first heading was the type of memory: STM or LTM. Twenty-nine studies included STM tests and 39 studies used LTM tests. The second heading was the type of material used to test memory. In the domain of LTM, 27 studies used verbal material, 13 visual material, 4 visuospatial material. Under the heading of STM, 19 studies used verbal material, 11 visual material and 16 visuospatial material.

Insert Table 1 – Characteristics of the included studies.

The next heading was the type of retrieval, which was divided into three sub-headings: free recall, cued recall and recognition. In the studies of LTM, 19 used recognition tasks, 20 free recall and 6 cued recall tasks. For STM, 9 studies used recognition and 24 used free recall tasks. No studies used a short-term cued recall task. The last heading was the type of processing or organization of the items: associative, serial, semantic or none. Seventeen studies used a serial processing evaluation STM (2 studies were also tested in LTM), 16 studies used associative processing evaluation LTM (2 studies were also tested in STM), and 9 studies involved semantic processing. All of these last studies focused on LTM and used verbal material except one that used visual material.

Insert Figure 2 – PRISMA Flowchart of literature search.

3. Meta-Analysis results

3.1. Short-term versus long-term memory

Considering STM in autism, the first aim of the present meta-analysis was to determinate if active storage by rehearsal, that mainly differentiates STM and LTM, is impaired or not, by calculating and comparing overall short-term and long-term memory performance (Table 2).

Analysis of STM performance revealed a significant difference between ASD and TD groups, with a medium effect size with the ASD participants performing at a lower level than TD participants (Hedges' g= -0.53 [-0.90; -0.16], p=.005). There was, however a significant degree of heterogeneity (I^2=96%). Diminished ASD performance was also observed in LTM tasks with a low to medium effect size (Hedges' g= -0.30 [-0.42; -0.17], p<.00001), without significant heterogeneity (I^2=24%). Although the effect size was greater for STM than for LTM, the analyses of subgroup differences that compared STM with LTM were not significant (I^2= 25.6%) (see Supplementary Table 3).

Insert Table 2 – Short-term versus Long-term memory analyses.

3.2. Short-term memory

3.2.1. Effect of additional memory control

We identified a medium effect size for both STM tasks without additional cognitive control (Hedges' g= -0.53 [-0.68; -0.38], p<.00001, I^2=22%) and STM tasks plus additional cognitive control, i.e. N-back and backward tasks (Hedges ' g= -0.58 [-1.01; -0.14], p=.009, I^2=96%). Subgroup analyses did not reveal any difference (I^2=0%), suggesting that additional cognitive control does not impair further STM difficulties (see Supplementary Table 4).

3.2.2. Types of material

The second aim on STM domain was to evaluate the hypothesized dissociation between impaired visuospatial STM and preserved verbal STM in ASD, by estimating STM performance depending on the type of material. Results revealed a medium effect size for both verbal STM (Hedges‘ g= -0.51 [-0.67; -0.35], p<.00001, I^2=46%) and visual STM (Hedges‘ g= -0.38 [-0.64; -0.11], p=.005, I^2=59%), and a medium to large effect for visuospatial STM (Hedges‘ g= -0.74 [-1.20; -0.28], p=.002) with however a greater heterogeneity (I^2=96%) (see Supplementary Table 5). Subgroup analyses among these domains did not reveal any difference (I^2=0%), suggesting homogeneous STM difficulties whatever the type of material at encoding.

3.2.3. Types of memory retrieval

The third aim in relation to STM performance was to evaluate STM performance in ASD depending on the type of retrieval, given the absence of available data. Both groups showed comparable performance in recognition tasks (Hedges‘ g= -0.33 [-0.68; 0.02], *p*=.07, I^2=59%). However, ASD participants showed significant reductions in free recall with a medium effect size (Hedges‘ g= -0.59 [-0.98; -0.19], *p*=.004, I^2=96%). The subgroup difference between the two types of retrieval was not significant (I^2=0%). In conclusion, ASD individuals have more difficulty when they do not have support for retrieval from STM but this reduction in performance was not sufficiently large to yield significant differences in subgroup analyses. (see Supplementary Table 6)

To evaluate if this pattern of results depends or not on the type of material, we calculated recognition and free recall STM performance for verbal, visual, and visuospatial material at encoding. For verbal material, we also identified preserved recognition (Hedges‘ g= -0.11 [-1.08; 0.85], *p*=.82,

I^2=74%) but with only two studies, and diminished free recall (Hedges' g= -0.50 [-0.67; -0.34], *p*<.00001, I^2=49%), with no significant subgroup difference (I^2=0%) (see Supplementary Table 7). For visual material, we identified the same pattern with preserved recognition (Hedges' g= -0.23 [-0.67; 0.21], *p*=.30, I^2=66%) and diminished free recall (Hedges' g= -0.53 [-0.80; -0.26], *p*=.0001, I^2=47%), without significant subgroup difference (I^2=20.5%) (see Supplementary Table 8). In the visuospatial domain, we identified preserved recognition (Hedges' g= -0.25 [-0.72; 0.22], *p*=.29, I^2=0%) and diminished free recall (Hedges' g= -0.77 [-1.24 ; -0.29], *p*=.002, I^2=96%), with a significant subgroup difference (I^2=56%) (see Supplementary Table 9). The performance of ASD participants was significantly diminished for free recall. Hence, this set of analyses confirms the STM pattern of preserved recognition while diminished free recall, irrespective of the type of material, albeit with insufficiently large differences between conditions to yield significant differences in subgroup analyses.

3.2.4. Organization of material

Finally, we aimed to evaluate the order recall in STM and the related temporal impairment hypothesis, by the comparison of serial recall versus non-serial recall. Results showed a medium effect size for both serial (Hedges' g= -0.62 [-1.09; -0.15], *p*=.009, I^2=96%) and non-serial (Hedges' g= -0.50 [-0.65; -0.35], *p*<.00001, I^2=50%) order memory (see Supplementary Table 10). The subgroup difference was not significant (I^2=0%), suggesting that serial order STM is impaired in the same extend that non-serial.

Insert Table 3 – Effect of material, type of retrieval task and organization of material on STM in individuals with ASD.

Hence, following the questions addressed by this meta-analysis, the results have identified a medium reduction in STM in autism, for both STM tasks both with and without additional cognitive control (i.e. N-back and backward tasks). These difficulties were homogeneous depending on the type of material, which goes against the hypothesized dissociation between impaired visuospatial STM and preserved verbal STM. We identified a pattern of unimpaired STM recognition while a medium deficit in STM free recall, consistent across the type of material, which suggests an extension of the *Task Support Hypothesis* to STM. Finally, we identified a medium effect size for both non-serial and serial STM, that confirms the impairment of order recall in STM in ASD but does not show a greater impairment of serial over non-serial STM. Table 3 presents the synthesized results on different domains in STM.

3.3. Long-term memory

3.3.1. Differences between short-term and long-term memory difficulties in ASD

Considering episodic memory in ASD, the first objective was to determinate if the pattern of memory preservations and impairments differs from STM, given the close relationship between STM and LTM. For this purpose, we carried out subgroup comparisons between LTM and STM in ASD, evaluating the type of material and the type of retrieval. We identified that verbal material only was less impaired in LTM than STM (I^2=84.4%, *p*=.01) (see Table 4, Supplementary Table 18).

3.3.2. Types of material

The second aim on LTM was to confirm the hypothesized superiority of visuospatial memory over verbal memory. Hence, we conducted analyses comparing these two types of material. For verbal material, individuals with ASD showed reduced performance with however a small effect size (Hedges' g= -0.21 [-0.38; -0.05], *p*=.01, I^2=27%). A greater reduction in performance was observed for visual material with a medium effect size (Hedges' g= -0.41 [-0.63; -0.19], *p*=.0002, I^2=42%). For visuospatial material, the ASD and TD individuals showed similar levels of performance, however the range of the effect sizes was large (Hedges' g= -0.31 [-0.90; 0.29], *p*=.31), with significant heterogeneity (I^2=77%) (see Supplementary Table 11). However, only four studies were used for this comparison, which may limit the power of the analysis leading to inconclusive results. The subgroup difference was not significant (I^2=1.1%). Together, these results argue in favor of a small deficit only in verbal LTM with a medium impairment in visual memory, albeit no significant subgroup difference (I^2=1.1%, p=0.36).

3.3.3. Types of memory retrieval

The third aim was to evaluate the efficiency of the supported retrieval (i.e. cued recall and recognition) compared to recall tests on episodic retrieval in ASD. When the retrieval task was either a recognition or a cued recall paradigm, performance of the individuals with ASD was similar to that of the TD group (recognition: Hedges' g= -0.15 [-0.35; 0.06], p=.16, I^2=35%; cued recall: Hedges' g= -0.08 [-0.36; 0.20], p=.58, I^2=0%). For free recall, the ASD participants exhibited significantly reduced performance with a small to medium effect size (Hedges' g= -0.38 [-0.53; -0.22], p<.00001, I^2=9%). Subgroup analyses between the types of retrieval approached significance (I^2=61.2%), suggesting a trend for better supported than unsupported retrieval in ASD (see Supplementary Table 12).

Further, we also aimed to evaluate if this pattern of results depends or not on the type of material. In the verbal domain, we identified preserved supported retrieval (recognition: Hedges' g= -0.09 [-0.35; 0.18], *p*=.51, I^2=38%; cued recall: Hedges' g= -0.08 [-0.36; 0.20], *p*=.58, I^2=0%) and diminished free recall (Hedges' g= -0.33 [-0.52; -0.14], *p*=.0005, I^2=0%), with no significant subgroup difference (I^2=39.4%) (see Supplementary Table 13). In the visual domain, we identified the same pattern with preserved recognition (Hedges' g= -0.29 [-0.62; 0.05], *p*=.10, I^2=43%) and diminished free recall (Hedges' g= -0.45 [-0.73; -0.17], *p*=.002, I^2=46%), without significant subgroup difference (I^2=0%) (see Supplementary Table 14). For visuospatial material, all studies except one used a recognition task therefore between group comparisons regarding the type of retrieval were not performed. Together, these results confirm the increased memory performance for supported retrieval, irrespective of the type of material.

3.3.4. Organization of material

Finally, we aimed to evaluate if associative memory is more adversely altered than item-memory as suggested by the hippocampal relational deficit account, and if individuals with ASD draw less benefit from semantic relatedness to foster memory as it does in typical conditions.

First, we conducted analyses on associations, as defined by the Binding Item-Context model (i.e. item – item, and item – context associations; Ranganath, 2010) without semantic relatedness. Both groups obtained comparable scores for associative memory tasks (Hedges' g= -0.19 [-0.56; 0.18], *p*=.31) but the heterogeneity between studies was significant (I^2=80%) (see Supplementary Table 15). By contrast, when analyses were conducted on non-associative tasks, we observed diminished performance in the ASD group with a small effect size (Hedges' g= -0.26 [-0.44; -0.07], *p*=.006, I^2=41%). Subgroup analyses were not significant (I^2=0%).

Second, we conducted analyses on tasks manipulating semantic relatedness (pairs, triplets, and lists of words in LTM). Performance in individuals with ASD was lower than that of TD individuals, with large albeit at best marginally significant effect size (Hedges' g= -1.05 [-2.16; 0.05], *p*=.06, I^2=88%) (see Supplementary Table 16). This reduced performance in the ASD group disappeared for tasks where there was no semantic manipulation (Hedges' g= -0.06 [-0.29; 0.17], *p*=.62, I^2=42%). In addition, the subgroup analyses were not significant, but we observed a large heterogeneity among subgroups (I^2=66.6%). Taken together, our results show a trend for difficulties in memory with semantic associations in ASD, but no significant differences.

Third, we conducted analyses on all tasks that manipulated associations as a whole, irrespective of association type (i.e. item – item, item – context) or semantic relatedness (i.e. with or without). ASD participants performed significantly lower that TD participants, with a small to medium effect size (Hedges' g= -0.38 [-0.56; -0.19], *p*<.0001, I^2=41%) (see Supplemental Table 17). For tasks requiring no association, there was also a small to medium significant effect size for the difference between ASD and TD participants (Hedges' g= -0.26 [-0.44; -0.07], *p*=.006, I^2=41%). Hence, it seems that ASD participants have the same difficulties in memorizing associated and non-associated information.

Insert Table 4 – Effect of material and type of retrieval task between LTM and STM in individuals with ASD.

Insert Table 5 – Effect of material, type of retrieval task and material organization on LTM in individuals with ASD.

Hence, following the working hypothesis addressed in this meta-analysis, the results have identified that the pattern of episodic memory preservation and impairments differs from that in STM, with verbal LTM being significantly less impaired than verbal STM. The results did not confirm the superiority of visuospatial LTM over verbal LTM, possibly because of significant heterogeneity and lack of statistical power for visuospatial material. Instead, the results identified a small effect size for verbal material only and a medium effect size for visual material, albeit with no significant difference. In line with our working hypothesis, we identified a preserved supported retrieval (i.e. cued recall and recognition), while a small to medium deficit in recall tests, irrespective of the type of material. Finally, we did not identify greater difficulties for associative compared to non-associative memory contrary to working hypothesis. By contrast, results showed a trend for diminished ASD memory in tasks manipulating semantic relatedness, in line with assumptions that suggest impairments at encoding or organization of to-be-memorized information. Table 5 presents the synthesized results on different domains in LTM.

4. Meta-regression

To examine the impact of potential variances, the moderator analysis was performed based on age, IQ (FSIQ) and ADOS score of ASD participants (Table 6). The meta-regression results showed that age and IQ of ASD individuals were significant factors in influencing STM (β=0.047, 95%CI (0.009, 0.086), p=0.02 and β=0.090, 95%CI (0.064, 0.117), p<0.0001, respectively) (Figure 3). However, there was no significant association for LTM (all p>0.05). The ADOS score was presented in only 5 studies, not allowing us to conclude on a potential association between this variable and STM or LTM.

Insert Table 6 - *Moderator analysis for the effects of ASD group vs. TD group by the characteristics of the ASD participants*

Insert Figure 3 – A. Plot of the difference in STM performance between ASD and TD groups depending on the severity of autistic disorder evaluated by age of ASD group. B. Plot of the difference in STM performance between ASD and TD groups depending on the severity of autistic disorder evaluated by FSIQ of ASD group.

5. Sensitivity analysis

Sensitivity analyses did not alter our findings (Supplementary Table 28) thus demonstrating the robustness of our results.

DISCUSSION

This meta-analysis focused on STM and episodic LTM in ASD. Statistical analyses for STM show an overall medium effect size of the between group difference with overall lower performance in the ASD group, regardless of the type of material. This is accompanied by preserved recognition as well as an ASD-related reduction in free recall with medium effect size. The analyses of long-term memory identified a more complex pattern of results, with a small effect size for verbal material only, with a medium effect size for visual material, with lower performance in the ASD group. Visuospatial LTM was preserved in ASD but this result was obtained on the basis of only a few studies. As for STM retrieval, we identified preserved recognition and a medium impairment for free recall, accompanied by preserved cued recall in ASD. Analyses of the organization of material for both STM and LTM show more heterogeneous results. We discuss these findings in the light of the known cognitive and neuroimaging features of ASD.

1. Short-term memory profile in autism

One of the strengths of this meta-analysis is to have distinguished and compared STM and LTM tests, which is a distinction that is rarely drawn in studies on memory in autism. Our results revealed that STM is more adversely affected than LTM, arguing in favor of multistore models of memory, which distinguish short- and long-term stores that, while separate from each other, nevertheless interact (see Norris, 2017 for review). We observed a medium effect size with high heterogeneity for STM regardless of the type of material (i.e. verbal, visual, and visuospatial), which suggests an alteration of underlying processes that are common to different stimulus types. Furthermore, tasks involving additional cognitive control (i.e. N-back and backward tasks) are not more impaired than others. This medium effect size is slightly smaller than in Wang et *al.*'s. (2017) study which reported a medium to large WM impairment in ASD, possibly reflecting additional difficulties in manipulating material that go beyond memory storage.

1.1. Overall medium impairment suggests difficulties with short-term maintenance

Active storage is the main process thought to distinguish short-term maintenance from LTM (see Norris, 2017 for a review of STM, and Baddeley & Hitch, 2019 for a review of WM). Actiive storage depends on two main types of cognitive operations either in STM or WM: the temporary activation of pre-existing long-term representations (i.e. semantic memory) and the rehearsal process that maintains items in the focus of attention in order to prevent decay (Cowan, 2008, 2017; Eriksson et *al.*, 2015; Jonides et *al.*, 2008). We suggest that neuropsychological factors specific to ASD may limit this two-step process in STM.

First, STM and WM theories are at one in proposing that short-term maintenance is supported by semantic long-term representations. The *STM as activated LTM* account suggests that short-term storage consists in a temporarily activated subset of information from semantic long-term representations into a focus of attention (Acheson, MacDonald, & Postle, 2011; Cowan, 2008; 2019; Jonides *et al.*, 2008; Lewis-Peacock & Postle, 2008; Thorn & Page, 2009). Recent WM models suggest that attention enables a strong overlap between perceptual information and related LTM representations (reviewed in Eriksson *et al.*, 2015). These models consistently highlight the role of attentional capacities, notably selective attention and sustained attention (Eriksson et al, 2015; Oberauer *et al.*, 2018), that positively correlate with verbal (e.g. Majerus *et al.*, 2012), visual and spatial (e.g. Menegaux *et al.*, 2019) STM performance in TD individuals, while a deficit in these attentional processes is a common feature in autism (with or without comorbid Attention Deficit Hyperactivity Disorder – ADHD, see Craig *et al.*, 2016 for review). As a result, positive correlations have been reported between attentional difficulties and reduced visual or visuospatial STM in adolescents with ASD (Chien *et al.*, 2015), as well as with reduced verbal STM in adults (Koolen *et al.*, 2012, but see Jiang, Capistrano, & Palm, 2014 for contradictory results). Some studies also reported increased difficulties in verbal STM (Takeuchi et *al.*, 2013) and visuospatial WM (Sinzig et *al.*, 2008) in ASD children and adolescents who have comorbid ADHD, while improvements in both sustained attention and visuospatial STM are noted after training sessions in children with ASD (de Vries et *al.*, 2015). In older individuals with ASD, Geurts & Vissers (2012) reported both diminished sustained attention and visual STM compared to controls, but no correlation was reported. Hence, and in line with cognitive theories of short-term storage, we hypothesize that attentional difficulties in ASD may weaken the association between the to-be-memorized information and their related semantic long-term representations, contrary to what occurs in TD individuals.

Second, rehearsal is described as the controlled sequence of retrievals and re-encodings of information into the focus of attention to prevent interference or decay. In both the STM and WM models rehearsal is observed in the phonological loop and to a lesser extent in the visuospatial sketchpad described by Baddeley (see Baddeley, 1996, 2019 for reviews). Rehearsal results in a complex combination of elementary cognitive processes, some being classified as executive functions, such as shifting, updating, and inhibition (see Jonides *et al.*, 2008, for maintenance in STM and Eriksson et al, 2015 for maintenance in WM). Hence, we hypothesize that executive dysfunction in ASD (Ozonoff *et al.*, 1991; Russell, 1997), and the related overall medium deficit in executive functions identified in two recent meta-analyses (Demetriou *et al.*, 2018; Lai *et al.*, 2017), may impair the rehearsal process during short-term maintenance.

At the cerebral level, neuroimaging studies have consistently provided evidence of the ability of the cortex to generate a persistent neural activity in the absence of stimuli during STM storage. Anterior prefrontal cortex and associated executive areas support the selective attention toward the to-be-memorized information and rehearsal processes in relation to the task-set (reviewed in D'Esposito & Postle, 2015; Norris, 2017; Smith, 1999), while representation and maintenance of items are supported by the same specialized perceptual areas that are recruited during the low-level processing of items at encoding (*sensory-recruitment hypothesis*, Pasternak & Greenlee, 2005, and see Serences, 2016, for review). Hence, we suggest that structural and functional long-distance underconnectivity in ASD may disrupt the antero-posterior communication associated with active storage, as previously hypothesized for WM (Barendse *et al.*, 2013). In particular, white matter integrity of the longitudinal and occipito-frontal fasciculi and uncinate fasciculus have been associated with the typical development of and performance in STM (Krogsrud *et al.*, 2018), while alterations of these association fibers are consistently reported in Diffusion Tensor Imaging studies in ASD (reviewed in Rane *et al.*, 2015). In addition, reduced functional connectivity is often reported between frontal/prefrontal areas and posterior brain regions during cognitive tasks (underconnectivity theory of autism, Just *et al.*, 2012) and at rest (reviewed in O'Reilly *et al.*, 2017).

Finally, in the meta-regression reported here, analyses identified that the overall reduction in STM decreases with age. This age effect may relate to the developmental trajectory of STM and WM in the TD population, where performance declines around adolescence as a result of functional reorganization of brain processes (Gómez *et al.*, 2018). We also identified that the overall reduction in STM decreases as full-scale intelligence quotient increases, possibly because test procedures used to measure both domains have common elements.

1.2. Similar moderately diminished performance across different types of material

Our results did not confirm a dissociation between preserved verbal STM and impaired visuospatial STM in ASD. Instead, we identified a medium effect size for both visual and verbal material, and a medium to large effect size for visuospatial material which was associated with a large heterogeneity, preventing any conclusion about a greater deficit. This pattern of results seems consistent with findings from Habib *et al*'s. (2019) meta-analysis in WM, which concluded that the phonological loop was as impaired as the visuospatial sketchpad in ASD. In addition, tests for subgroup differences between STM and LTM were only significant for verbal material.

ASD-related reductions in active storage processes may account for overall medium STM difficulties, across type of material. Beyond, the more significant difficulties in verbal STM compared to verbal LTM may suggest a specific difficulty with verbal encoding in STM. Both STM and WM models draw a major distinction between verbal encoding in short-term store compared to LTM, the former relying more on acoustic/phonological codes, and the latter on the semantic properties of items (see Thorn & Page, 2009 for STM review, and Baddeley & Hitch, 2019 for WM review). We hypothesize that a less semantically-based encoding may underlie verbal STM in ASD. In that sense, Norbury, Griffiths, & Nation (2010) demonstrated that new word learning relies more on the phonological codes of words and less on their semantic features in children with ASD, while the opposite pattern is observed in TD children, which leads to diminished learning and consolidation in ASD. More recently, Gladfelter & Goffman (2018) reviewed that word production in ASD is weakly associated to their semantic representations, and demonstrated that providing semantically rich information facilitates word learning. Hence, it seems possible that the phonological code of verbal STM interacts with a tendency in ASD to represent words more phonologically at the expense of their semantic features, leading to verbal STM being less supported by long term semantic representations during encoding and storage.

Furthermore, encoding and storage in verbal STM require the operation of multimodal processes: auditory or verbally presented words are recoded into their phonological form after contact with LTM representations (i.e. *STM as activated LTM* account). They are then rehearsed by subvocal articulation, which constitutes the verbal short-term maintenance (Baddeley, 2003; Baddeley & Hitch, 2019; Norris, 2017). We hypothesize that this multimodality affects information integration in short-term maintenance, as suggested in a more general sense in ASD (Martínez *et al.*, 2019).

1.3. Preserved recognition in the presence of impaired free recall

The present results suggest a dissociation between preserved STM recognition while impaired STM free recall, being consistent across type of material. This result seems important given that STM retrieval processes have received little consideration in ASD studies, or leading to discrepant findings (see Boucher, Mayes, & Bigham, 2012 for review).

Interestingly, we identified the same pattern of results within episodic LTM, which suggests an overall difficulties with free recall accompanied by overall preserved recognition in ASD. In TD individuals, neuroimaging studies have consistently identified a strong overlap in the neural substrates for retrieval after short-term and long-term delays (reviewed in Jonides *et al.*, 2008, for STM, and Jeneson & Squire, 2011, for WM). Hence, we hypothesize that atypical neural processes identified in neuroimaging studies of episodic retrieval in ASD (e.g. Cooper *et al.*, 2017) may also lead to STM retrieval deficits. This finding also extends the *Task Support Hypothesis* to STM, by showing that providing a support at test, i.e. a recognition task, normalizes STM performance.

The fact that the effect size for verbal STM free recall was not smaller than that for visual and visuospatial material raises a theoretical point regarding the retrieval phase in verbal STM. When verbal information is degraded at the point of recall, redintegration, a specifically verbal process, enables a reconstruction of these partially degraded memory traces by selecting long-term lexical representations that match the phonological traces (Acheson, MacDonald, & Postle, 2011; Poirier *et al.*, 2015; and reviewed in Norris, 2017). Mottron *et al.* (2013) suggested a non-strategic redintegration process in ASD individuals who also have savant syndrome and hyperlexia during episodic retrieval. We hypothesize that an atypical recruitment of this process may limit STM verbal recall, as observed in other developmental disorders such as specific language impairment (Riches, 2012).

1.4. Serial Recall

Our results revealed that serial and other STM tasks lead diminished performance to a similar extent in individuals with ASD. Taken together, statistical analyses on STM overall as well as on the type of material at encoding and the type of retrieval, suggest that all stages of STM may be impaired in ASD. Most of all, attentional and executive difficulties in ASD may limit the activation of a subset of information stored in LTM in the absence of sensory input, as well as its subsequent rehearsal during active maintenance. This may be related to the antero-posterior underconnectivity in ASD. In addition, STM may be less supported by long-term representations in ASD at each of the stages at which STM and LTM interact, i.e. mainly storage, but also at encoding and retrieval (according to Norris, 2017). Close to this hypothesis, Mammarella *et al.* (2014) noticed that individuals with ASD do not benefit from a higher semantic configuration of a Visual Pattern Test during a STM task, suggesting that they are unable to make use of their semantic memory to construct a global representation of an array in order to enhance its memorization. Specifically verbal processes may further limit this STM/LTM interaction at encoding (more supported by phonological codes of items at the expense of their lexical codes) and possibly at retrieval (a possible lack of redintegration process).

2. <u>Episodic long-term memory profile in ASD</u>

2.1. Fewer difficulties in episodic LTM compared to STM

We identified a small to medium effect size for overall reduced LTM in ASD with low heterogeneity, and subgroup differences that depended on the type of material at encoding and the type of retrieval, suggesting that impaired processes in episodic memory in ASD are more related to encoding and retrieval than storage. This pattern is contrary to that seen in the STM results, which pointed more to a primary deficit in storage.

Lower difficulties in episodic LTM compared to STM in individuals with ASD result from greater interactions between the episodic memory system and the semantic memory system than is the case for STM since the semantic memory system tends to be relatively preserved in individuals with high-functioning ASD (although with ASD-specific characteristics: see Ben Shalom's, 2003 account and Boucher *et al*.'s., 2012 for review). In that sense, neuropsychological studies in TD individuals have evidenced a strong interdependence of episodic and semantic memory systems (see Greenberg & Verfaellie, 2010 for review), confirmed by neuroimaging studies showing a great overlap between the networks of episodic and semantic memory (see Palacio & Cardenas, 2019 for review). By contrast, STM is rather dedicated to the learning of new information (see Norris, 2017 for review), and the *sensory-recruitment hypothesis* derived from neuroimaging studies posits maintenance of items in a perceptual form by the same specialized perceptual areas as at encoding (Pasternak & Greenlee, 2005).

Similarly to STM, both executive dysfunction and antero-posterior underconnectivity may account for episodic difficulties in ASD. Regarding the former, Maister *et al.* (2013) suggested a more effortful and less automatic associative retrieval in children with ASD compared to TD peers. In adults with ASD, Barnard *et al.* (2008) speculated that planning difficulties could be specifically related to learning disabilities, and Bowler *et al.* (2014) hypothesized that associative memory difficulties result from both executive and binding impairments related to frontal and hippocampal dysfunctions. Prefrontal and frontal executive areas along with medial temporal lobes are strongly associated with

LTM (reviewed in Jeong *et al.*, 2015), and white matter integrity of the uncinate fasciculus and cingulum have been associated with typical development and performance of episodic LTM (Wendelken *et al.*, 2015). By contrast, Diffusion Tensor Imaging studies have consistently identified alterations of these association fibers in ASD (see Rane *et al.*, 2015 for review). For functional connectivity, only one study has been conducted in ASD, identifying that recollection deficits may be related to hippocampal underconnectivity (Cooper *et al.*, 2017).

2.2. Small deficit only for verbal material but medium deficit for visual material

Our results did not confirm superior visuospatial over verbal episodic LTM. Instead, we identified a small effect size for verbal material, a medium one for visual and a non-significant effect for visuospatial material. This limited difficulty in verbal memory is an important finding, which may be helpful for therapists and caregivers of individuals with HFA and may provide new opportunities for memory rehabilitation (e.g. learning, narrative memory). By contrast, difficulties with visual LTM is an unexpected result given that visual LTM is often described as a strength in ASD (e.g. Jiang *et al.*, 2015) that is thought to be related to enhanced perceptual functioning (e.g. Mottron *et al.*, 2009). Here, we develop possible explanations for this difference.

First, LTM for visual material may need a greater degree of executive function than verbal material. Busch *et al.* (2005) suggest that episodic retrieval for visual material necessitates keeping an ongoing activated mental representation, a process that needs more resources than for words. Hence, it seems possible that executive dysfunction in ASD (Lai *et al.*, 2017; Ozonoff *et al.*, 1991; Russell, 1997) contributes to greater difficulties in visual LTM .

Second, pictures have both visual and verbal codes (*dual-coding hypothesis*, Paivio, 1971), and their representations in LTM hierarchically associate low-level perceptual features and high-level conceptual (i.e. semantic) category-specific features (Brady *et al.*, 2011). In TD individuals, the richness of pictorial stimuli enhances their episodic memorization and fosters recollection (*distinctiveness* *heuristic hypothesis*, Schacter *et al.*, 1999), which leads to better memory for pictures over words (*picture superiority effect*, Nelson *et al.,* 1976). By contrast, memory for words is less dependent on perception, and relies mainly on pre-existing semantic knowledge (Ferreira *et al.*, 2015). In ASD, perceptual functioning is characterized by enhanced low-level processing with reduced levels-of-processing effects (i.e. participants do not benefit more from semantic rather than superficial encoding, Mottron *et al.*, 2001; Toichi & Kamio, 2002), and the *weak central coherence* hypothesis also posits a bias towards local and featural processing, resulting in diminished global processing (Happé & Frith, 2006). Hence, we hypothesize that visual LTM in ASD is more perceptually-driven and less conceptually-driven relative to verbal LTM. According to this argument, hierarchical models of memory posit that encoding in the episodic system depends on the quality of encoding in the inferior semantic system (*SPI model*, Tulving, 1995; *MNESIS model*, Eustache *et al.*, 2016), which is supported by the findings of Parra *et al.* (2016), who reported that memory for semantically-related pictures in ASD is enhanced by associating the name of pictures, suggesting that words would foster item and inter-item conceptual processing, leading to better memory.

Particular neurophysiological characteristics in ASD also argue in favor of visual LTM being less supported by semantic knowledge than verbal memory, leading to diminished performance. In their review, O'Reilly *et al.* (2017) concluded that there was an abnormal lateralization of functional connectivity in ASD, with an elevated left-over-right electrophysiological connectivity ratio compared to TD individuals, both during cognitive tasks and at rest. According to hemispheric brain specialization (i.e. left and right hemispheres being specialized towards local-featural, and global-configural processing, respectively), they suggested that this leftward lateralization would reflect the tendency in ASD to process more local components at the expense of the global relationships among components. Fiebelkorn *et al.* (2013) identified this pattern in an earlier study and concluded that there was an atypical conceptual processing of pictures in ASD arising from typical hemispheric specialization coupled with atypical hemispheric isolation (resulting from diminished inter-hemispheric connectivity), leading to reduced local/global integration.

Finally, because only four studies of visuospatial material with heterogeneous results have been included in the meta-analysis, we cannot draw any definitive conclusions about memory for this type of material in ASD. Further data are needed to formulate more definitive hypotheses. We are left with two tentative conclusions, namely that on the one hand undiminished or superior visuospatial abilities have been suggested as being characteristic to ASD (Caron *et al.*, 2004; Edgin & Pennington, 2005) and on the other hand, that the hippocampus – the brain structure involved *inter alia* in memory for locations (Ekstrom & Ranganath, 2017) – may be impaired in ASD (Lind *et al.*, 2013; Lind *et al.*, 2014; Ring *et al*., 2017, 2018a, 2018b).

2.3. Improvement of memory performance when retrieval is supported

Our results demonstrated difficulties in ASD for free recall with preserved cued recall and recognition, regardless of type of material. This pattern of results confirms the *Task Support Hypothesis* (TSH) in ASD (Bowler *et al.*, 1997, 2004; Gaigg *et al.*, 2008), which distinguishes supported tasks with typical levels of performance (cued recall and recognition), from unsupported ones (mainly free recall) which are routinely difficult for people with ASD.

The absence of significant difficulties with cued recall and recognition is in accordance with the TSH and constitutes a potential avenue for memory rehabilitation. The *task support* effect may contribute to the typical levels of performance for cued recall relative to free recall (e.g. Phelan *et al.*, 2011) in two ways: providing an effective retrieval cue facilitates the mental reinstatement of the same contextual state as at encoding (Rugg & Vilberg, 2013), and thus activates a smaller set of potential targets (Unsworth *et al.*, 2012). Second, the dual-process theory of recognition evokes two successive and independent processes: familiarity, supported by the semantic system and associated with noetic awareness, and recognition, associated with the episodic system and autonoetic awareness (Yonelinas, 2002). Since familiarity can support recognition for single items or items interactively encoded (Desaunay *et al.*, 2017), intact or enhanced familiarity in ASD (Bowler *et al.*, 2000; 2007) could support this preserved recognition (Gaigg *et al.*, 2015; Massand *et al.*, 2013).

Executive dysfunction (Lai *et al.*, 2017; Ozonoff *et al.*, 1991; Russell, 1997) may also contribute to this pattern of results, since memory search and response generation places a high demand on the executive system. A general model of controlled retrieval implies the interaction between information stored in memory and contextual retrieval cues, either external (i.e. environmental) or internal (i.e. self-generated) (reviewed in Mecklinger, 2010). These retrieval cues trigger the mental reinstatement of the same contextual state existing at encoding (Manning *et al.*, 2012; Polyn & Kahana, 2008), as initially suggested by Tulving's notion of "mental time travel". Memory search is self-initiated during free recall and driven by interacting, internally-maintained context representations over a long time-scale alongside newly reactivated item representations (temporal context model, Howard & Kahana, 2002; Polyn & Kahana, 2008). In ASD, mental reinstatement of internal and external contexts appears to be diminished, which leads to difficulties in free recall. This is borne out by studies in which participants are interviewed as eyewitnesses of scenes or as victims of crime. In supported conditions, e.g. physically returning to the same environment where encoding took place (Maras & Bowler, 2012) or sketch reinstatement of context (Mattison *et al.*, 2015), recall performance improved. This hypothesis is also congruent with the pattern of retrieval awareness in ASD (e.g. Gaigg *et al.*, 2015), characterized by unimpaired familiarity (a context-free process), with diminished recollection (a context-dependent recognition process) (Yonelinas, 1997; 2002).

These difficulties to search retrieval cues may also be related to STM difficulties in ASD, following Unsworth's model of memory. Unsworth & Spillers (2010) have suggested in TD individuals that limited capacities in STM are related to free recall difficulties in LTM, because of inefficient hierarchical processes involved in retrieval cue search. The model postulates that people use an overarching general cue rather than particular retrieval cues to retrieve items (see Unsworth *et al.*, 2012 for review), and suggests that participants with lower free recall capacities search through a larger set of cues and therefore experience difficulties resolving cue overload both at encoding and retrieval (Unsworth, 2016). The same difficulties may arise in individuals with ASD. This suggests that provision of a semantic cue during study or recall of semantically related items would enhance their performance, which is consistently reported by studies testing the TSH (e.g. Bowler *et al.*, 2008, 2010; Gaigg *et al.*, 2008). Hence, semantic contextual cues at encoding might enhance the inter-item relational processing and facilitate the reinstatement of the same semantic context representation at test, which will drive the recall process, and may activate a smaller set of potential targets (Polyn *et al.*, 2009).

2.4. Inter-item memory in ASD

Contrary to our working hypothesis, memory for all types of association was diminished to the same extent as that of non-associative memory. Moreover, the effect sizes for item-item and item-context unrelated associations were not significantly different from but rather, associated with large heterogeneity. The confidence intervals included zero, which prevents any clear conclusions on associative memory in ASD. A number of studies have demonstrated that the hippocampus supports inter-item and item-context associations in various tasks (e.g. Bird, 2017; Ranganath, 2010; Rugg *et al.*, 2012), and studies that focused on associative memory in ASD often report difficulties that are thought to be related to hippocampal dysfunction (reviewed in Boucher *et al.*, 2012). However, areas surrounding the hippocampus may compensate for difficulties in hippocampal associative memory, as suggested by Gaigg *et al.* (2008). In particular, the perirhinal cortex can support within- and between-domain associative memory for unitized items in TD subjects (reviewed in Zimmer & Ecker, 2010). This level of memory processes might be recruited to a greater extent as a compensatory strategy by individuals with ASD. Other compensatory strategies may be mediated by frontal regions (Gaigg *et al.*, 2015) but may depend on the material memorized and the age of participants (see Solomon *et al.,* 2016 for contradictory results).

Finally, the tentative confirmation of diminished memory for semantically-related information is in line with the existing literature set out in earlier paragraphs (Hermelin & O'Connor, 1970), although, as with associative memory, the confidence interval included zero, thereby preventing any definitive conclusion. It is possible that this result stems from an absence of levels-of-processing effects in ASD (Toichi & Kamio, 2002), as well as diminished generation of memory cues during encoding or retrieval (Bowler *et al.*, 2010), as discussed previously. Instead, individuals with ASD may use perceptually-driven rather than semantic or conceptual processes, which may help them in tasks on which typically developed individuals draw on semantic processes (see Bowler *et al.*, 2008).

3. Limitations

This study contains several limitations. Although we carried out a large number of statistical tests, we did not control for the risk of alpha-inflation. However, it should be noted that even though we did not apply a Bonferroni correction, our significant p-values were often less than .005 or even less than .001. In addition, we were unable to draw definitive conclusions from some comparisons because of a lack of power resulting from there being very few studies in a particular domain. For example, we were able to include only four studies in the visuospatial domain in LTM, which had contradictory results, necessitating further investigations in this area. For some studies, we calculated an effect size composite to avoid repeated analyses of the same participants. However, this had the effect of reducing the variance with a consequent diminution of its capacity to truly represent the underlying population. However, this was mitigated to some extent in the more specific, sub-group analyses (e.g. where the variability of the visual LTM data was different from that of the verbal LTM data).

Our overall conclusions must also be qualified by the fact that several of our outcomes had a significant degree of heterogeneity. There were very few standardized tests to evaluate memory; rather, each test was specifically aimed at answering a specific scientific question. Furthermore, this heterogeneity results from the inherently large variability in ASD. To take into account the impact of these heterogeneities, we used a random effect models in our analyses.

Finally, all studies included in this meta-analysis were carried out on participants without documented comorbidity or intellectual disability, and often on participants with a diagnosis of

Asperger's syndrome. These individuals can be thought of as not being representative of "typical" ASD. According to some studies, only 10% of people with ASD have a diagnosis of Asperger's syndrome and according to Sharma *et al.* (2018), nearly 75% of people diagnosed with ASD have comorbid psychiatric illnesses or conditions. Thus, the generalization of results to all autistic individuals is limited. However, the application of these inclusion criteria is necessary to ensure sufficient homogeneity to conduct a meta-analysis. Indeed, studies of ASD accompanied by intellectual disability are generally not included, because they need to be tested on tasks that are very different from those suitable for individuals with no intellectual disability. Although there are weaknesses in terms of the representativeness of the participant pool in this meta-analysis of the wider ASD population, the results can, nevertheless provide pointers to how these excluded groups might be included in further studies. For example, identifying fronto-hippocampal involvement using tasks with non-intellectually-disabled people with ASD can point to the usefulness of using paradigms derived from the animal hippocampal lesion literature, which would be suitable for people with intellectual disabilities (see, for example Ring et al., 2017).

CONCLUSION

This meta-analysis reveals the patterns of strength and weakness in the STM and LTM performance of individuals with high functioning Autism or Asperger syndrome. We identified a limited deficit in verbal LTM and preserved overall recognition and cued recall, possibly resulting from a greater overlap of these memory tasks with semantic long-term representations. By contrast, individuals with ASD may experience difficulties in memory tasks that have lower overlap with the semantic system or involve additional cognitive operations possibly including executive demands such as STM or free recall. Taken together, our findings highlight the need to support STM functioning in ASD and acknowledge the potential benefit of using verbal materials at encoding as well as broader forms of memory support at retrieval in order to enhance performance.

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DATA SHARING

https://osf.io/6rj7w/?view_only=f0dffe6811e1447686a559128ed19407

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Tables

Table 1 – Characteristics of the included studies.

*WISC: Wechsler Intelligence Scale for Children (Wechsler, 2003); AWMA: Automated Working Memory Assessment (Alloway, 2007); WAIS: Weschler Adult Intelligence Scales, (Wechsler, 2008); CVLT-C: California Verbal Learning Test - Children's Version. * To avoid repetition of the same study population in the statistical analysis, some studies, with the same first author, need to be deleted when the other study is present in the comparison. The studies, which were deleted, were those with the lowest number, or the least test, or the lowest quality. If the number was the same, then we looked at the number of tests, then the quality. (1)(2) In the same study, several experiments with two populations neither completely independent nor completely repeated. During the statistical analyses, one of the experiments can be deleted if the other experiment is present in the comparison to avoid the repetition of the same subjects. (A) (B) (C) In the same study, tests are performed on different study populations that are completely independent of each other. During the statistical analyses, each study population is treated as independent studies.*

Table 2 – Short-term versus Long-term memory analyses.

*SMD : Standardized mean difference ; CI: Confidence Interval; * The forest plot reporting the comparison between ASD and control people are reported in supplementary table 3.*

Table 3 – Effect of material, type of retrieval task and organization of material on STM in individuals with ASD.

*SMD : Standardized mean difference ; CI: Confidence Interval; NR: No result found because of insufficiently study enrollment in the comparison * Forest plots reporting comparisons between ASD and control people are reported in supplementary tables (4, 5, 6, 7, 8, 9, 10).*

Table 4 – Effect of material and type of retrieval task between LTM and STM in individuals with ASD.

** Forest plots reporting comparisons between ASD and control people are reported in supplementary tables (18, 19, 20, 21, 22, 23, 24, 25, 26, 27).*

Table 5 – Effect of material, type of retrieval task and material organization on LTM in individuals with ASD.

*SMD : Standardized mean difference ; CI: Confidence Interval; * Forest plots reporting comparisons between ASD and control people are reported in supplementary tables (11, 12, 13, 14, 15, 16, 17).*

Table 6 - Moderator analysis for the effects of ASD group vs. TD group by the characteristics of the ASD participants

Figures

Figure 1: Categorization of memory tests. Organisation divided into four levels: 1) short-term versus long-term memory 2) type of material 3) type of retrieval task 4) organisation of the content of the material.

Figure 2: PRISMA Flowchart of literature search. [(1)] 64 studies included in total but whose study population is not always totally independent between studies. In the end, 53 studies are completely independent. The remaining 11 studies were included in the analyses only when the other studies with the same participants were not present.

Figure 3: A. Plot of the difference in STM performance between ASD and TD groups depending on the severity of autistic disorder evaluated by age of ASD group. B. Plot of the difference in STM performance between ASD and TD groups depending on the severity of autistic disorder evaluated by FSIQ of ASD group.

Table 1 page1

Study Name	Patient group				Control group			Memory Task	Stimuli	Memory Organisation	STM/LTM	Modified or Unmodified STM	Type of retrieval
	Diagnoses	N (male)	Age (SD)	FSIQ (SD)	N (male)	Age (SD)	FSIQ (SD)						
Abbasy *et al.* , 2018	ADOS DSM-5	1540 (1020)	9.2 (1.6)	91.32 (23.42)	1490 (970)	9.4 (2.3)	102.4 (14.48)	Spatial span forward and backward, CANTABexpedio	Visuo-spatial spatial span	Serial	STM	Modified	Recall: free
Alloway *et al* ., 2016	ADOS DSM-4/ICD-10	26 (23)	8.4 (3)	79.12 (17.74)	23 (12)	10.5 (0.5)	99.83 (11.2)	Digit span task, WISC	Verbal: digits	Serial	STM	Modified	Recall: free
								Digit recall task, AWMA	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Word recall, AWMA	Verbal: words	Serial	STM	Unmodified	Recall: free
								Listening recall, AWMA	Verbal: sentence	-	STM	modified	Recall: free
								Backward digit recall, AWMA	Verbal: digits	-	STM	Modified	Recall: free
								Maze memory task, AWMA	Visuo-spatial: path drawn on a maze	-	STM	Unmodified	Recall: free
								Block recall task, AWMA	Visuo-spatial: sequence of tapped blocks	Serial	STM	Unmodified	Recall: free
								position of a dot in a matrices	Visuo-spatial: position of a dot in a matrices	-	STM	Unmodified	Recall: free
								Odd-one-out task, AWMA	Visuo-spatial: shape	-	STM	Unmodified	Recall: free
								letter-number sequencing	Verbal: letters, numbers	-	STM	Modified	Recall: free
Biscaldi *et al.* , 2016	ADI/ADOS DSM-4/ICD-10	18 (16)	10.98 (1.76)	107.44 (22.79)	33 (28)	10.69 (1.88)	103.32 (17.28)	N-back task: mean of 0-back and 1-back	Visual: schematic drawings	-	STM	Modified	Recognition
Blair *et al.* , 2002	DSM-4	12 (12)	29.92 (7.62)	89.58 (12.23)	12 (9)	31.08 (6.78)	80.83 (13.87)	Word list recognition test, Warrington	Verbal: words	-	LTM	-	Recognition
								Recognition memory test for cats, Warrington	Visual: pictures	-	LTM	-	Recognition
								Recognition memory test for horses, Warrington	Visual: pictures	-	LTM	-	Recognition
								Recognition memory test for motobikes, Warrington	Visual: pictures	-	LTM	-	Recognition
								Recognition memory test for leaves, Warrington	Visual: pictures	-	LTM	-	Recognition
								Recognition memory test for buildings, Warrington	Visual: pictures	-	LTM	-	Recognition
Bowler *et al.* , 1997	ICD-10	16 (10)	31.2 (11)	94.06 (18.2)	16 (8)	33.3 (11.4)	95.94 (11.95)	Unrelated word list, free recall	Verbal: word lists	-	LTM	-	Recall: free
								Related word list, free recall	Verbal: word lists	Semantic	LTM	-	Recall: free
Bowler *et al.* , 2000	ICD-10	16 (13)	30.9 (6.26)	90.8 (14.6)	15 (14)	31.1 (5.63)	92.9 (12.4)	Recognition task, high-frequency word	Verbal: word lists	-	LTM	-	Recognition
Bowler *et al.* , 2007*	ICD-10	18 (14)	33 (10.7)	98 (17.1)	18 (15)	34 (8.7)	102 (14.9)	Recognition of word list, full attention condition	Verbal: words list	-	LTM	-	Recognition
Bowler *et al.* , 2008 (1)*	DSM-4	20 (17)	35.66 (13.66)	108.79 (21.63)	20 (16)	34.38 (12.16)	107.22 (17.27)	Target – context related word pairs, recall of target words	Verbal: word pairs	Semantic	LTM	-	Recall: free
								Target – context related word pairs, recall of context words	Verbal: word pairs	Associative Semantic	LTM	-	Recall: free
								Target – context unrelated word pairs, recall of target words	Verbal: word pairs	-	LTM	-	Recall: free

Table1 page2

								Target – context unrelated word pairs, recall of context words	Verbal: word pairs	Associative	LTM	-	Recall: free
Bowler *et al.* , 2008 (2)*	DSM-4	20 (13)	31.8 (11.23)	96.16 (18.25)	20 (13)	34.52 (11.92)	101.06 (13.25)	Target – context related word pairs, recognition of target words	Verbal: word pairs	-	LTM	-	Recognition
								Target – context related word pairs, recognition of context words	Verbal: word pairs	Associative Semantic	LTM	-	Recognition
								Target – context unrelated word pairs, recognition of target words	Verbal: word pairs	-	LTM	-	Recognition
								Target – context unrelated word pairs, recognition of context words	Verbal: word pairs	Associative	LTM	-	Recognition
Bowler *et al.* , 2008*	DSM-4/ICD-10	16 (10)	31 (10.4)	99 (14.2)	16 (13)	34 (8.6)	102 (12.4)	Oral free recall of 16 words individualy presented	Vebal: words	-	LTM	-	Recall: free
								Written free recall of 16 words individualy presented	Vebal: words	-	LTM	-	Recall: free
Bowler *et al.* , 2010*	ADOS DSM-4	16 (13)	35.7 (13.6)	103.7 (16.4)	16 (13)	34.2 (12.3)	106.87 (14.1)	related words list recall, no encoding cue, no retrieval cue	Verbal: words list	Semantic	LTM	-	Recall: free
								related words list recall, encoding semantic cue, no retrieval cue	Verbal: words list	Semantic	LTM	-	Recall: free
								related words list recall, no encoding cue, retrieval semantic cue	Verbal: words list	Semantic	LTM	-	Recall: cued
								related words list recall, encoding semantic cue, retrieval semantic cue	Verbal: words list	Semantic	LTM	-	Recall: cued
								related words list recall, no encoding cue, no retrieval cue	Verbal: words list	Semantic	LTM	-	Recall: free
								related words list recall, encoding semantic cue, no retrieval cue	Verbal: words list	Semantic	LTM	-	Recall: free
								related words list recall, no encoding cue, retrieval semantic cue	Verbal: words list	Semantic	LTM	-	Recall: cued
								related words list recall, encoding semantic cue, retrieval semantic cue	Verbal: words list	Semantic	LTM	-	Recall: cued
Bowler *et al.* , 2014 (1)*	ADOS DSM-4	18 (13)	37 (13.4)	104.2 (15.5)	18 (14)	34.8 (10.9)	104.3 (15.1)	item recognition test	Visual: line drawing of objects	-	LTM	-	Recognition
								location recognition test	Visuo-spatial: line drawing of objects	-	LTM	-	Recognition
Bowler *et al.* , 2014 (2)*	ADOS DSM-4	14 (11)	38.01 (13.8)	104.4 (13.8)	15 (13)	37.1 (11.4)	101.5 (11.1)	item-color recognition test	Visual: coloured drawings of objects	Associative	LTM	-	Recognition
								item-location recognition test	Visuo-spatial: coloured drawings of objects	Associative	LTM	-	Recognition
Bowler *et al.* , 2015*	ADOS DSM-4	18 (13)	36 (13.5)	107.2 (20.5)	18 (14)	33.6 (11.5)	106.6 (16.4)	three lists of nine words : recognition of words	Verbal: word lists	-	LTM	-	Recognition
Braden *et al.* , 2017	ADOS DSM-4/DSM-5	16 (16)	50.1 (1.7)	108.9 (3.4)	17 (17)	50 (1.8)	110.2 (2.7)	1-back task	Verbal: letters	-	STM	Modified	Recognition
								2-back task	Verbal: letters	-	STM	Modified	Recognition
Chen *et al.* , 2016 (A)	ADI DSM-4	53 (48)	9.96 (1.37)	108.58 (15.97)	63 (58)	10.65 (1.31)	114.94 (8.92)	Digit span forward, WISC-3	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Digit span backward, WISC-3	Verbal: digits	-	STM	Modified	Recall: free
								Spatial span, CANTAB	Visuo-spatial: sequence of color-changing boxes	-	STM	Unmodified	Recall: free
Chen *et al.* , 2016 (B)	ADI DSM-4	58 (57)	14.72 (1.53)	107.07 (12.83)	51 (50)	14.41 (1.42)	109.92 (9.54)	Digit span forward, WISC-3	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Digit span backward, WISC-3	Verbal: digits	-	STM	Modified	Recall: free

Table1 page3

								Spatial span, CANTAB	Visuo-spatial: sequence of colour-changing boxes	-	STM	Unmodified	Recall: free
Christ *et al.* , 2017	ADI/ADOS	22 (22)	12.3 (1.1)	100.5 (13.1)	22 (22)	12.8 (0.9)	103.4 (7.2)	Spatial span, Wechsler scales	Visuo-spatial: spatial subtest	-	STM	Modified	Recall: free
								Digit span, Wechsler scales	Verbal: digits	-	STM	Modified	Recall: free
Cooper *et al.* , 2015	DSM-4/ICD-10	24 (11)	31.75 (7.58)	116.33 (8.63)	24 (11)	31 (6.51)	116.54 (7.61)	item recognition test	Visual: items among a scene	Associative	LTM	-	Recognition
								item-location recognition test	Visuo-spatial: location of items among a scene	Associative	LTM	-	Recognition
Cui *et al.* , 2010	DSM-4	12 (11)	7.46 (0.84)	100.03 (17.13)	29 (24)	7.37 (0.48)	108.31 (14.08)	Digit recall span, WMTB	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Digit recall score, WMTB	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Word recall, WMTB	Verbal: words list	Serial	STM	Unmodified	Recall: free
								Word recall score, WMTB	Verbal: words list	Serial	STM	Unmodified	Recall: free
								Backward digit recall span, WMTB	Verbal: digits	-	STM	Modified	Recall: free
								Backward digit recall score, WMTB	Verbal: digits	-	STM	Modified	Recall: free
								Counting recall span, WMTB	Visual: dots	Serial	STM	Unmodified	Recall: free
								Counting recall score, WMTB	Visual: dots	Serial	STM	Unmodified	Recall: free
								Spatial recall span, WMTB	Visuo-spatial: sequence of tapped blocks	Serial	STM	Unmodified	Recall: free
								Spatial recall score, WMTB	Visuo-spatial: sequence of tapped blocks	Serial	STM	Unmodified	Recall: free
								1-back digit	Verbal: digit	-	STM	Modified	Recognition
								2-back digit	Verbal: digit	-	STM	Modified	Recognition
								1-back figure	Visual: geometric figure	-	STM	Modified	Recognition
								2-back figure	Visual: geometric figure	-	STM	Modified	Recognition
								1-back location	Visuo-spatial: location of a circle	-	STM	Modified	Recognition
								2-back location	Visuo-spatial: location of a circle	-	STM	Modified	Recognition
Funabiki *et al.* , 2018	DSM-4	64 (38)	30.98 (8.62)	109 (10.45)	30 (17)	28.03 (7.94)	112 (11.96)	Visual Reproduction I subtest, WMS-R	Visual Reproduction I subtest	-	STM	Unmodified	Recall: free
								Visual Memory Span subtest, WMS-R	Verbal Visual Memory Span subtest	Serial	STM	Unmodified	Recall: free
								Digit span forward, WMS-R	Verbal digits	Serial	STM	Unmodified	Recall: free
								Visual Memory Span subtest backward, WMS-R	Verbal Visual Memory Span subtest	Serial	STM	Modified	Recall: free
								Digit span backward, WMS-R	Verbal digits	Serial	STM	Modified	Recall: free
								Visual Paired Associates I subtest, WMS-R	Visual Visual Paired Associates I subtest	-	LTM	-	Recall: free

Table1 page4

								Verbal Paired Associates I subtest (easy), WMS-R	Verbal Verbal Paired Associates I subtest	-	LTM	-	Recall: free
								Verbal Paired Associates I subtest (difficult), WMS-R	Verbal Verbal Paired Associates I subtest	-	LTM	-	Recall: free
Gaigg *et al.* , 2008*	DSM-4	20 (13)	34.3 (14.2)	102 (18)	20 (13)	30.4 (9.8)	104 (14)	2 related words list recall	Verbal: words list	Semantic	LTM	-	Recall: free
								16 related words list recall	Verbal: words list	Semantic	LTM	-	Recall: free
Gaigg *et al.* , 2008*	ADOS DSM-4	18 (15)	32.8 (12.4)	106.3 (17.2)	18 (14)	33.2 (13.6)	105.1 (12.1)	Free recall of related and neutral 16 words list	Verbal: words list	Semantic	LTM	-	Recall: free
								Free recall of related and neutral 16 words list	Verbal: words list	Semantic	LTM	-	Recall: free
								Free recall of unrelated and neutral 16 words list	Verbal: words list	-	LTM	-	Recall: free
								Free recall of unrelated and neutral 16 words list	Verbal: words list	-	LTM	-	Recall: free
Gaigg *et al., 2015*	ADOS DSM-4	13 (12)	35.6 (10.3)	106.2 (16.3)	12 (11)	35.5 (10.5)	110.2 (14.8)	Word triplets recognition task, unrelated (0-link)	Verbal: word triplets	Associative	LTM	-	Recognition
								Word triplets recognition task, related (2-link)	Verbal: word triplets	Associative Semantic	LTM	-	Recognition
Garcia-Molina *et al.* , 2019	ADI/ADOS	30 (25)	9.4 (1.55)	102.83 (14.23)	30 (23)	9.53 (1.59)	107.03 (12.02)	Reverse Memory subscale of the Leiter-R recall	Visual: reverse Memory subscale of the Leiter-R	Serial	STM	Modified	Recall: free
								Digit span forward and backward, WISC-4	Verbal digits	Serial	STM	Modified	Recall: free
Geurts *et al.* , 2004	ADI DSM-4/ICD-10	41 (41)	9.4 (1.8)	98.3 (18.4)	41 (NK)	9.1 (1.7)	111.5 (18)	Corsi block tapping test, spatial span	Visuo-spatial: sequence of taped blocks	Serial	STM	Unmodified	Recall: free
								Benton Visual Retention Test	Visual: pattern	-	STM	Unmodified	Recall: free
Grainger *et al.* , 2014*	ADOS DSM-4/ICD-10	18 (13)	28.96 (10.28)	112.33 (15)	18 (11)	30.43 (14.59)	114.94 (10.5)	Feeling-of-knowing task: proportion of targets recalled	Verbal: word pairs (cue-target)	Associative	LTM	-	Recall: cued
								Feeling-of-knowing task: proportion of targets recognised	Verbal: word pairs (cue-target)	-	LTM	-	Recognition
Grainger *et al.* , 2016*	DSM-4/ICD-10	22 (19)	13.42 (1.12)	106.73 (11.84)	20 (20)	13.22 (1.01)	109.5 (15)	Intention superiority task: read condition	Verbal: action phrases	-	LTM	-	Recognition
Grainger *et al.* , 2016 (1)*	ADI DSM-4/ICD-10	18 (13)	28.96 (10.28)	112.33 (15)	18 (11)	30.43 (14.59)	114.94 (10.5)	Cued recall memory task	Verbal: word pairs	Associative	LTM	-	Recall: cued
Grainger *et al.* , 2016 (2)*	SRS DSM-4	22 (19)	13.7 (1.45)	100.95 (14.06)	21 (19)	13.21 (1.18)	101.14 (13.68)	Cued recall memory task	Verbal: word pairs	Associative	LTM	-	Recall: cued
Komeda *et al.* , 2013	DSM-4	18 (17)	26.3 (6.7)	105.3 (14.1)	17 (16)	26.9 (5.3)	110.4 (7)	Recognition task about the target sentence of each story	Verbal: short sentence	-	LTM	-	Recognition
Kouklari *et al.* , 2017	ADI/ADOS DSM-4	79 (65)	11.27 (2.56)	95.85 (15.09)	91 (60)	10.8 (2.49)	99.78 (13.54)	Digit span, Wechsler scales	Verbal: digits	-	STM	Modified	Recall: free
Li *et al.* , 2017	DSM-5	32 (32)	10.31 (3.34)	94.44 (20.53)	39 (39)	10.72 (2.21)	111.38 (11.29)	Digit span, Wechsler scales	Verbal: digits	-	STM	Modified	Recall: free
								Letter-number sequencing WISC	Verbal: letters, numbers	-	STM	Modified	Recall: free
Lind *et al* ., 2014	ADI/ADOS DSM-4	20 (16)	8.67 (1.37)	105.65 (16.34)	20 (15)	8.32 (0.91)	109.05 (8.68)	item-background associative recognition	Visual: item and background	Associative	LTM	-	Recognition
Lopez *et al.* , 2008	DSM-3/DSM-4/ ICD-10	15 (NK)	13.1 (2.4)	87.13 (24.93)	16 (NK)	14.4 (0.1)	98.75 (16.2)	Recall verbally the pictures	Visual: pictures	Semantic	LTM	-	Recall: free
								Recall verbally the pictures	Visual: pictures	-	LTM	-	Recall: free
Loth *et al.,* 2011 (A)	ADOS DSM-4/ICD-10	25 (25)	12.08 (2)	107.5 (21.2)	20 (20)	10.33 (2.33)	101.8 (17.5)	Recall of items seen in the scene	Visual: line-drawing scene	Associative	LTM	-	Recall: free

Table1 page5

Loth *et al.* , 2011 (B)	ADOS DSM-4/ICD-10	13 (11)	27.5 (12.17)	108 (18.1)	14 (11)	23.33 (3.67)	118.1 (11.8)	Recall of items seen in the scene	Visual: line-drawing scene	Associative	LTM	-	Recall: free
Mammarella *et al.* , 2019	ADI DSM-4/ICD-10	17 (NK)	13.54 (2.93)	91.71 (6.25)	17 (NK)	13.72 (3.82)	98.82 (7.02)	Visuospatial working memory task, minimum	Visuo-spatial working memory task	-	STM	Unmodified	Recall: free
								Visuospatial working memory task, intermediate	Visuo-spatial working memory task	-	STM	Unmodified	Recall: free
								Visuospatial working memory task, maximum	Visuo-spatial working memory task	-	STM	-	Recall: free
Martínez *et al.* , 2017	ADOS DSM-4	21 (21)	12.67 (2.6)	98.88 (18.5)	21 (21)	12.95 (3)	106.33 (10.05)	Digit span forward, Wechsler scales	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Digit span backward, Wechsler scales	Verbal: digits	-	STM	Modified	Recall: free
								Letter-number sequencing Wechsler Scales	Verbal: letters, numbers	-	STM	Modified	Recall: free
Massand *et al.* , 2013	ADI/ADOS DSM-4	22 (20)	25.72 (4.76)	104.79 (11.98)	14 (12)	23.85 (3.74)	102.08 (12.19)	Old/new word repetition High frequency words	Verbal: words	-	LTM	-	Recognition
Massand *et al.* , 2015	ADOS DSM-4	15 (13)	38.89 (14.77)	114 (13)	18 (16)	37.17 (11.84)	111 (18)	item recognition test	Visual: items	-	LTM	-	Recognition
								item-color recognition test	Visual: coloured items	Associative	LTM	-	Recognition
Matsuura *et al.* , 2014	DSM-4	11 (11)	12 (2.2)	105.6 (14.3)	19 (12)	11.4 (1.6)	111.8 (13.4)	Delayed matching to sample, CANTAB	Visual: non-verbalisable patterns	-	STM	Unmodified	Recognition
								Spatial span, CANTAB	Visuo-spatial: sequence of squares	-	STM	Modified	Recall: free
Mayer *et al* ., 2014	ADOS DSM-4	19 (15)	40.23 (11.33)	113.37 (15.27)	19 (15)	38.31 (9.05)	118.95 (10.84)	Verbatim recall	Verbal: eared sentences (normal speed)	-	LTM	-	Recall: free
								digit span forward	Verbal: digits	Serial	STM	Unmodified	Recall: free
								digit span backward	Verbal: digits	-	STM	Modified	Recall: free
Meyer *et al.* , 2014	ADOS DSM-4/ICD-10	16 (12)	36.48 (11.72)	104.88 (17.56)	16 (10)	37.6 (13.91)	106.25 (13.86)	To-be-learned words, short cue-delay	Verbal: words	-	LTM	-	Recognition
								To-be-learned words, long cue-delay	Verbal: words	-	LTM	-	Recognition
Phelan *et al.* , 2011	ADI DSM-4	15 (12)	13.02 (2.4)	112.07 (13.54)	15 (12)	12.42 (2.5)	110.6 (11.2)	Short-delay free recall, CVLT-C	Verbal: word list	Serial	LTM	-	Recall: free
								Short-delay cued recall, CVLT-C	Verbal: items from 3 categories	Serial Semantic	LTM	-	Recall: cued
								Long-delay free recall, CVLT-C	Verbal: word list	Serial	LTM	-	Recall: free
								Long-delay cued recall, CVLT-C	Verbal: items from 3 categories	Serial Semantic	LTM	-	Recall: cued
								Word list recognition, CVLT-C	Verbal: items from 3 categories	Serial Semantic	LTM	-	Recognition
Poirier *et al.* , 2011 (1)	ADOS DSM-4	22 (16)	37.6 (13.3)	106.9 (18.8)	22 (17)	37.3 (11.3)	110.7 (12.6)	Immediate serial recall, correct-in-position	Verbal: words list	Serial	STM	Unmodified	Recall: free
								Immediate serial recall, irrespective of order	Verbal: words list	-	STM	Unmodified	Recall: free
Poirier *et al.* , 2011 (2)	ADOS DSM-4	18 (12)	40.3 (13.6)	107.8 (12.9)	18 (13)	41 (11.1)	107.2 (14.4)	Order recognition test	Verbal: words list	Serial	STM	Unmodified	Recognition
Powell *et al.* , 2017	ADOS	29 (24)	49 (11.7)	113.2 (9.5)	30 (23)	48.7 (12.1)	113.1 (10.2)	RAVLST, trial 1	Verbal: word lists	-	LTM	-	Recall: free
Renner *et al.* , 2000	DSM-4	14 (11)	10.17 (2.33)	99.29 (11.24)	14 (8)	9.33 (2)	110.71 (8.06)	Recognition explicit memory test	Visual: line drawing of objects	-	LTM	-	Recognition

Table1 page6

								Recall explicit memory test	Visual: line drawing of objects	-	LTM	-	Recall: free
Ring *et al.* , 2015*	ADOS DSM-4	25 (20)	42.13 (13.2)	108 (15.4)	23 (17)	40.87 (13.51)	113 (12.2)	Object-location task: location recognition	Visuo-spatial: location of an item in a background context	Associative	LTM	-	Recognition
Ring *et al.* , 2016*	ADOS DSM-4	18 (13)	42.78 (11.8)	108 (17.9)	18 (14)	43.48 (13)	109 (17.2)	Item task	Visual: triplet of shapes	Associative	STM	Unmodified	Recognition
								Location task	Visuo-spatial: triplet of shapes	Associative	STM	Unmodified	Recognition
								Order task	Visual: triplet of shapes	Associative	STM	Unmodified	Recognition
								Associative task	Visuo-spatial: triplet of shapes	Serial	STM	Unmodified	Recognition
Ring *et al.* , 2018*	ADOS DSM-4	37 (30)	42.61 (12.5)	110 (16.2)	31 (25)	40.71 (13.8)	114 (13.7)	Pictures (Animals) (out of 8) free recall test	Visual Animals (out of 8)	-	LTM	-	Recall: free
Smith *et al.* , 2007	ICD-10	12 (9)	40.09 (10.79)	104.33 (19)	12 (8)	39.94 (12.35)	105.83 (16.25)	Recall of related words list, untrained condition	Verbal: word lists	Semantic	LTM	-	Recall: free
								Recall of unrelated words list, untrained condition	Verbal: word lists	-	LTM	-	Recall: free
Souchay *et al.* , 2013	ADOS	19 (16)	14.15 (2.44)	112.06 (14.92)	19 (14)	13.18 (2.7)	116.22 (13.53)	Recognition of written items of previously seen items	Visual: pictures	-	LTM	-	Recognition:
Trontel *et al.* , 2013*	ADI/ADOS DSM-4	56 (56)	12 (4.37)	98.26 (16.63)	31 (31)	11.98 (4.01)	115.24 (15.57)	Object recall task, TOMAL	Visual: objets	-	LTM	-	Recall: free
Trontel *et al.* , 2015*	ADI/ADOS DSM-4	38 (38)	13.2 (4.1)	106.7 (12)	31 (31)	12 (4.2)	116.3 (14.9)	Object recall, TOMAL	Visual: objects	-	STM	Unmodified	Recall: free
								Digit span, forward, TOMAL	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Letter span, forward, TOMAL	Verbal: letters	Serial	STM	Unmodified	Recall: free
								Digit span, backward, TOMAL	Verbal: digits	-	STM	Modified	Recall: free
								Letter span, backward, TOMAL	Verbal: letters	-	STM	Modified	Recall: free
								Abstract visual memory, TOAML	Visual: abstract visual memory	-	STM	Unmodified	Recognition
								Visual sequential memory, TOMAL	Visuo-spatial: visual sequential memory	Serial	LTM	-	Recall: free
								Memory for locations, TOMAL	Visuo-spatial: memory for locations	Associative	STM	Unmodified	Recall: free
Urbain *et al.* , 2015*	ADOS	20 (16)	11.25 (1.58)	108.25 (14.31)	20 (13)	11.26 (1.64)	115.95 (10.97)	1-back figure	Visual: geometric figure	-	STM	Modified	Recognition
								2-back figure	Visual: geometric figure	-	STM	Modified	Recognition
Urbain *et al.* , 2015*	ADOS	17 (13)	11.17 (1.69)	109.94 (13.92)	20 (13)	11.26 (1.64)	115.95 (10.97)	2-back figure	Visual: geometric figure	-	STM	Modified	Recognition
Van Eylen *et al.* , 2015	DSM-4	50 (30)	12.21 (2.58)	104.32 (10.83)	50 (30)	12.48 (2.72)	107.72 (9.3)	Spatial span, Wechsler Non Verbal-NL	Visuo-spatial: sequence of taped blocks	-	STM	Modified	Recall: free
Verté *et al.* , 2005	ADI DSM-4	61 (57)	9.1 (1.9)	99.2 (17.1)	47 (40)	9.4 (1.6)	112.1 (9.7)	Benton Visual Retention Test	Visual: patterns	-	STM	Unmodified	Recall: free
								Corsi block tapping test, spatial span	Visuo-spatial: sequence of tapped blocks	Serial	STM	Unmodified	Recall: free
Vogan *et al.* , 2014	ADOS	19 (16)	11.05 (1.43)	109.42 (15.72)	17 (13)	11.12 (2)	115.35 (9.27)	Digit recall, WMTB-C	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Block recall, WMTB-C	Visuo-spatial: sequence of tapped blocks	Serial	STM	Unmodified	Recall: free

Table1 page7

								Mazes memory, WMTB-C	Visuo-spatial: path drawn on a maze	-	STM	Unmodified	Recall: free
								Listening recall, WMTB-C	Verbal: sentences	-	STM	modified	Recall: free
								Backward digit recall, WMTB-C	Verbal: digits	-	STM	Modified	Recall: free
Williams *et al.* , 2005	ADI/ADOS DSM-4	29 (26)	28.72 (10.44)	105.86 (14.19)	34 (30)	26.53 (10.22)	109.65 (11.39)	Verbal paired associates 1, WMS-3	Verbal: word pairs; WMS-3	Associative	LTM	-	Recall: cued
								Verbal paired associates 2, WMS-3	Verbal: word pairs ; WMS-3	Associative	LTM	-	Recall: cued
								Letter-number sequencing, WMS-3	Verbal: letters, numbers	-	STM	Modified	Recall: free
								Spatial span, WMS-3	Visuo-spatial: sequence of taped blocks	-	STM	Modified	Recall: free
Williams *et al.* , 2006*	ADI/ADOS	56 (46)	11.36 (2.18)	104.13 (15.09)	56 (39)	11.82 (2.2)	107.5 (8.21)	Digit span, WISC-3	Verbal: digits	-	STM	modified	Recall: free
Williams *et al.* , 2006*	ADI/ADOS	38 (NK)	11.68 (2.46)	103.82 (14.29)	38 (NK)	12.16 (2.19)	107.18 (9.37)	Digit span, WISC-3	Verbal: digits	-	STM	modified	Recall: free
								Finger windows, WRAMIL	Visuo-spatial: finger windows	Serial	STM	unmodified	Recall: free
								number/letter, WRAML	Verbal: letters, numbers	-	STM	modified	Recall: free
								sentence memory, WRAML	Verbal: sentence memory	-	STM	Unmodified	Recall: free
Williams *et al.* , 2012	ADOS DSM-4/ICD-10	17 (14)	42.13 (14.14)	114 (13.39)	17 (14)	39.43 (12.51)	116.71 (13.32)	Recall task, silent condition, control stimulus	Visual: pictures of objects	-	LTM	-	Recall: free
Williams *et al.* , 2014	ADOS DSM-4/ICD-10	17 (14)	31.06 (9.64)	114.06 (15.16)	17 (14)	31.92 (14.17)	117.71 (13.05)	Complex span task, verbal	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Complex span task, visual	Visuo-spatial: location of a square	Serial	STM	Unmodified	Recall: free
								Simple span task, verbal	Verbal: digits	Serial	STM	Unmodified	Recall: free
								Simple span task, visual	Visuo-spatial: location of a square	Serial	STM	Unmodified	Recall: free
Wojcik *et al.* , 2014	ADOS	21 (18)	12.77 (2.34)	112.19 (13.83)	21 (17)	11.64 (2.49)	116.67 (13.27)	Recall of unrelated word pair	Verbal: word pairs	Associative	LTM	-	Recall: cued
								Recall of unrelated word pair	Verbal: word pairs	Associative	LTM	-	Recall: cued
Yamamoto *et al.* , 2018	DSM-4/ICD-10	14 (8)	30.5 (6.86)	103.64 (9.94)	16 (7)	27.88 (10.1)	106.38 (12.58)	sentences recall test	Verbal sentences	-	LTM	-	Recall: free
Young *et al.* , 2019	ADI DSM-4/DSM-5	32 (20)	33.3 (13.8)	104.9 (14.3)	41 (15)	21.7 (5.9)	104.9 (10.1)	Verbal Paired Associates 15 recall, WMS	Verbal word pairs	Associative	LTM	-	Recall: free
Yuk *et al.* , 2018	ADOS	19 (16)	10.52 (1.45)	109.58 (12.05)	22 (19)	10.34 (1.32)	119.55 (9.49)	Digit span forward and backward, WMTB-C	Verbal digits	Serial	STM	Modified	Recall: free

Table2

Outcomes	Number of Trials	SMD	95% CI	p-value	I^2 %	Between-Group Heterogeneity			Publication Bias
						Q-Value	df(Q)	p(Q)	Egger's Test (p)
Comparison LTM vs STM *	56								
Short Term Memory	28	-0.53	-0.90 to -0.16	0.005	96%	607.9	27	<0.001	0.21
Long Term Memory	32	-0.30	-0.42 to -0.17	<0.001	24%	41.0	31	0.11	0.19

Table3

Outcomes	Number of Trials	SMD	95% CI	p-value	I² %	Between-Group Heterogeneity			Publication Bias
						Q-Value	df(Q)	p(Q)	Egger's Test (p)
Additional Memory Control									
Additional cognitive control *	28								
Plus additional cognitive control	22	-0.58	-1.01 to -0.14	0.009	96%	528.4	21	<0.001	0.30
Without additional cognitive control	17	-0.53	-0.68 to -0.38	<0.001	22%	20.6	16	0.2	0.02
Encoding Stage									
Type of material *	28								
Verbal	19	-0.51	-0.67 to -0.35	<0.001	46%	33.2	18	0.02	0.17
Visual	10	-0.38	-0.64 to -0.11	0.005	59%	22.1	9	0.009	0.12
Visuo-spatial	17	-0.74	-1.20 to -0.28	0.002	96%	357.0	15	<0.001	0.36
Information Retrieval Stage									
Type of retrieval *	28								
Recognition	8	-0.33	-0.68 to 0.02	0.07	59%	17.2	7	0.02	0.54
Free recall	24	-0.59	-0.98 to -0.19	0.004	96%	541.2	23	<0.001	0.24
Retrieval of verbal information *	19								
Recognition	2	-0.11	-1.08 to 0.85	0.82	74%	3.9	1	0.05	NR
Free recall	18	-0.50	-0.67 to -0.34	<0.001	49%	33.25	17	0.01	0.13
Retrieval of visual information *	10								
Recognition	6	-0.23	-0.67 to 0.21	0.30	66%	14.8	5	0.01	0.39
Free recall	6	-0.53	-0.80 to -0.26	<0.001	47%	9.5	5	0.09	0.19
Retrieval of visuo-spatial information *									
Recognition	2	-0.25	-0.72 to 0.22	0.29	0%	0.30	1	0.59	NR
Free recall	16	-0.77	-1.24 to -0.29	0.002	96%	341.9	15	<0.001	0.40
Memory organisation									
Serial memory *	28								
Serial memory	18	-0.62	-1.09 to -0.15	0.009	96%	404.8	17	<0.001	0.17
Non-Serial memory	23	-0.50	-0.65 to -0.35	<0.001	50%	44.0	22	0.004	0.10

Table4

Outcomes		I^2 %	Between-Subgroup Heterogeneity		
			Q-Value	df(Q)	p(Q)
Comparison LTM vs STM		25.6%	1.3	1	0.25
Type of material *	Verbal	84.4%	6.4	1	0.01
	Visual	0.0%	0.0	1	0.85
	Visuo-spatial	22.0%	1.3	1	0.26
Type of retrieval *	Recognition	0.0%	0.8	1	0.38
	Free recall	0.0%	0.9	1	0.34
Verbal according type of retrieval *	Recognition	0.0%	0.0	1	0.96
	Free recall	43.1%	1.8	1	0.18
Visual accoding type of retrieval *	Recognition	0.0%	0.0	1	0.85
	Free recall	0.0%	0.2	1	0.70
Visuo-spatial accoding type of retrieval *	Recognition	0.0%	0.1	1	0.74

Table5

Outcomes	Number of Trials	SMD	95% CI	p-value	I² %	Between-Group Heterogeneity			Publication Bias
						Q-Value	df(Q)	p(Q)	Egger's Test (p)
Encoding Stage									
Type of material *	35								
Verbal	21	-0.21	-0.38 to -0.05	0.01	27%	27.4	20	0.13	0.32
Visual	14	-0.41	-0.63 to -0.19	<0.001	42%	22.5	13	0.05	0.14
Visuo-spatial	4	-0.31	-0.90 to 0.29	0.31	77%	12.9	3	0.005	0.45
Information Retrieval Stage									
Type of retrieval *	34								
Recognition	17	-0.15	-0.35 to 0.06	0.16	35%	24.5	16	0.08	0.98
Cued recall	5	-0.08	-0.36 to 0.20	0.58	0%	3.8	4	0.44	0.77
Free recall	17	-0.38	-0.53 to -0.22	<0.001	9%	17.7	16	0.34	0.12
Retrieval of verbal information *	22								
Recognition	11	-0.09	-0.35 to 0.18	0.51	38%	16.1	10	0.1	0.58
Cued recall	5	-0.08	-0.36 to 0.20	0.58	0%	3.8	4	0.44	0.77
Free recall	10	-0.33	-0.52 to -0.14	<0.001	0%	8.3	9	0.5	0.34
Retrieval of visual information *	14								
Recognition	7	-0.29	-0.62 to 0.05	0.10	43%	10.5	6	0.11	0.24
Free recall	8	-0.45	-0.73 to -0.17	0.002	46%	13.0	7	0.07	0.29
Memory organisation									
Associative memory *	31								
Associative memory	14	-0.19	-0.56 to 0.18	0.31	80%	65.9	13	<0.001	0.13
Non-Associative memory	21	-0.26	-0.44 to -0.07	0.006	41%	33.8	20	0.31	0.06
Semantic link (verbal encoding) *	16								
Semantic link related	4	-1.05	-2.16 to 0.05	0.06	88%	25.3	3	<0.001	0.33
Semantic link unrelated	16	-0.06	-0.29 to 0.17	0.62	42%	25.9	15	0.04	0.36
Whole Associative *	33								
Whole Associative	19	-0.38	-0.56 to -0.19	<0.001	41%	30.4	18	0.03	0.18
No organisation	21	-0.26	-0.44 to -0.07	0.006	41%	33.8	20	0.03	0.06

Table6

	Long Term Memory			Short Term Memory		
Explanatory variables	**N**	**β (95%CI)**	**p**	**N**	**β (95%CI)**	**p**
Age mean of ASD	32	-0.006 (-0.017, 0.006)	0.33	28	0.047 (0.009, 0.086)	0.02
FSIQ mean of ASD	31	-0.003 (-0.024, 0.018)	0.77	28	0.090 (0.064, 0.117)	<0.001
ADOS score	5	0.192 (-0.745, 1.129)	0.56	5	0.144 (-0.282, 0.569)	0.36

Figure1

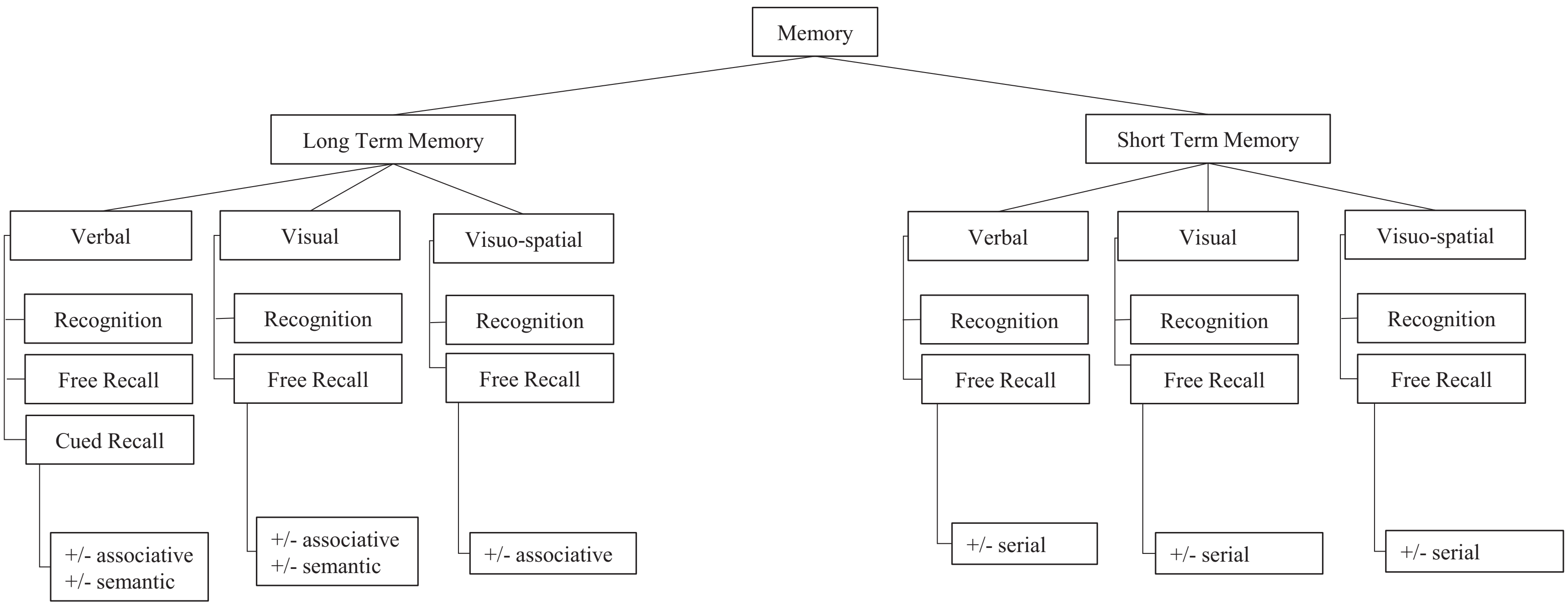

Memory
Long Term Memory
Short Term Memory
Verbal
Visual
Visuo-spatial
Recognition
Free Recall
Cued Recall
+/- associative
+/- semantic
Recognition
Free Recall
+/- associative
+/- semantic
Recognition
Free Recall
+/- associative
Verbal
Visual
Visuo-spatial
Recognition
Free Recall
+/- serial
Recognition
Free Recall
+/- serial
Recognition
Free Recall
+/- serial

Figure2

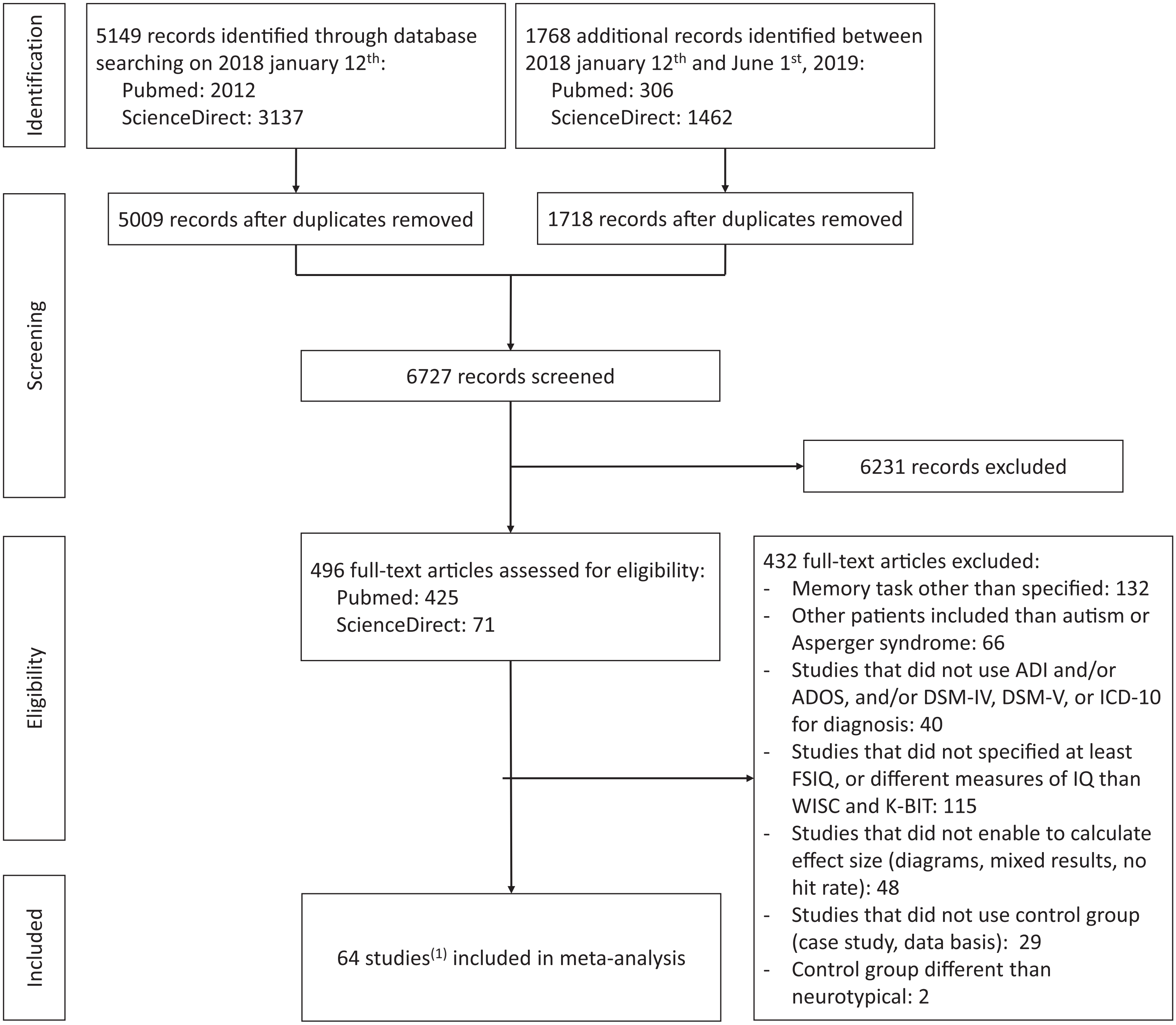
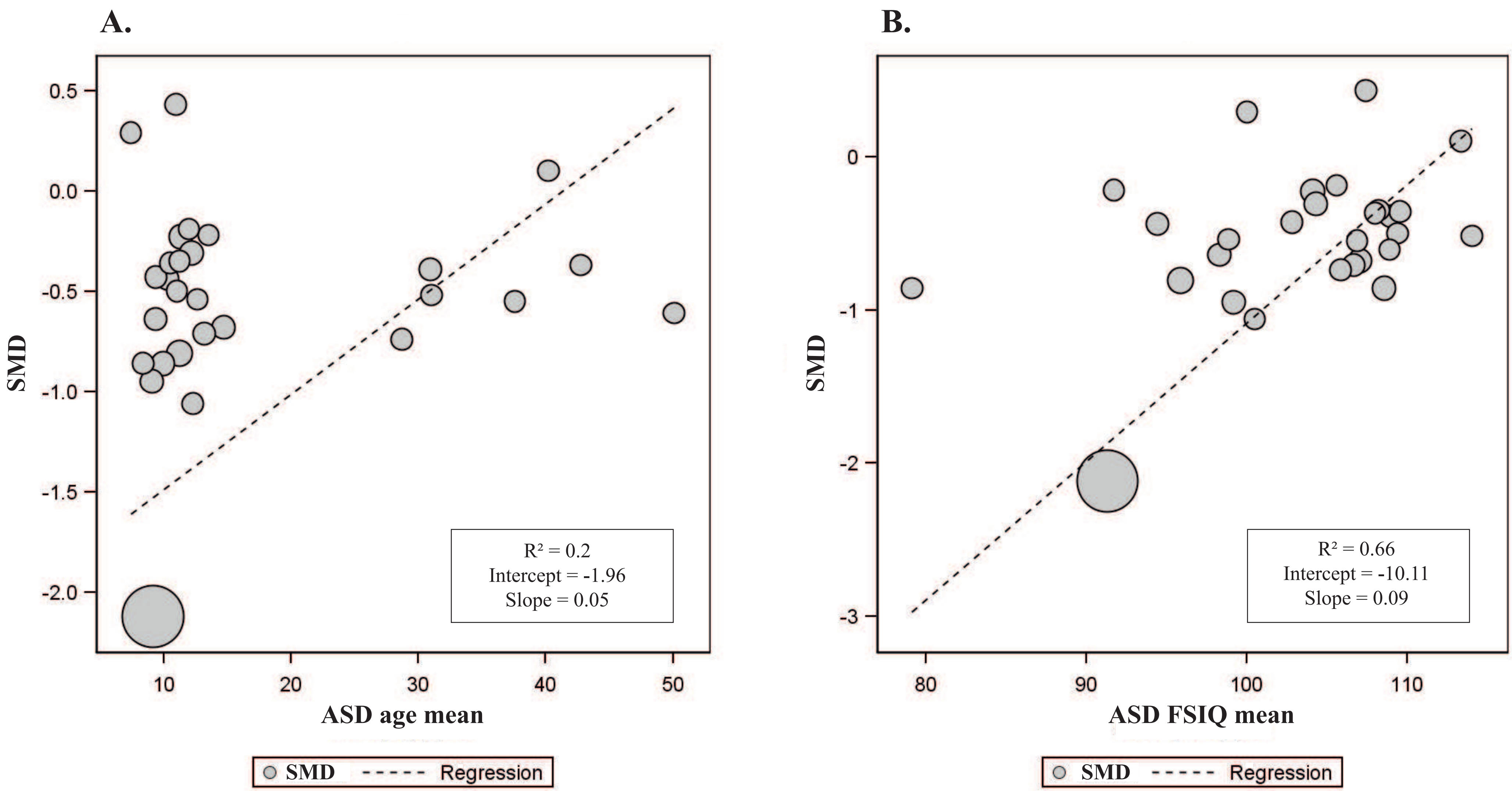

Identification
5149 records identified through database searching on 2018 january 12th:
Pubmed: 2012
ScienceDirect: 3137
1768 additional records identified between 2018 january 12th and June 1st, 2019:
Pubmed: 306
ScienceDirect: 1462
Screening
5009 records after duplicates removed
1718 records after duplicates removed
6727 records screened
6231 records excluded
Eligibility
496 full-text articles assessed for eligibility:
Pubmed: 425
ScienceDirect: 71
432 full-text articles excluded:
- Memory task other than specified: 132
- Other patients included than autism or Asperger syndrome: 66
- Studies that did not use ADI and/or ADOS, and/or DSM-IV, DSM-V, or ICD-10 for diagnosis: 40
- Studies that did not specified at least FSIQ, or different measures of IQ than WISC and K-BIT: 115
- Studies that did not enable to calculate effect size (diagrams, mixed results, no hit rate): 48
- Studies that did not use control group (case study, data basis): 29
- Control group different than neurotypical: 2
Included
64 studies(1) included in meta-analysis

Figure3


A.
SMD
0.5
0.0
-0.5
-1.0
-1.5
-2.0
10
20
30
40
50
ASD age mean
R² = 0.2
Intercept = -1.96
Slope = 0.05
SMD
Regression
B.
SMD
0
-1
-2
-3
80
90
100
110
ASD FSIQ mean
R² = 0.66
Intercept = -10.11
Slope = 0.09
SMD
Regression

Supplementary Table 1 - Description of domains and examples of included tasks for each domains

DOMAIN	DEFINITION	EXAMPLES OF TASKS IN THE META-ANALYSIS
VERBAL RECOGNITION	The ability to recognize verbal informations i.e. letters, numbers, words (single words, word pairs or triplets, word lists, sentences) among distractors: - immediately after presentation or after a delay - can be seriel, or associative - words can be semantically related, or unrelated	Recognition memory test for words (e.g. Warrington) Recognition of words into a list Recognition of a short sentence If seriel: Word lists (e.g. CVLT), semantically related or not, correct in position N-back digit recognition If associative: Words pairs, words triplets, semantically related or not List of words, semantically related or not
VERBAL RECALL	The ability to recall verbal information, i.e. letters, numbers, words (single words, word pairs or triplets, word lists, sentences): - immediately after presentation or after a delay - oral or written recall - words can be semantically related (with or without a cue) or unrelated	Oral or written recall of individualy presented words Recall of words list, semantically related or not, irrespective of order Free recall of eared sentences If seriel: Word list (e.g. CVLT), semantically related (cued recall) or not, correct in position Digit span or letter span, forward or backward (e.g. TOMAL, WMTB-C, WRAML) Letter-number sequencing Last word of a sentence If associative: Recall of a target word, of cue-target word pairs (i.e WMS-3)
VISUAL RECOGNITION	The ability to recognize visually presented informations, i.e. pictures or drawings: - immediately after presentation or after a delay - pictures can be concrete or abstract, simple or complex	Item recognition test Recognition memory test for cats, horses, motorbikes, leaves (Warrington) Delayed matching to sample (CANTAB) If seriel: N-back of schematic drawings or figure recognition If associative: Item-colour relational memory Item change (items among a scene) Item-background Triplets of shapes, item test or associative test
VISUAL RECALL	The ability to orally recall visually presented informations, i.e. pictures or dawings, representing concrete objects: - immediately after presentation or after a delay	Verbal recall of line drawings or pictures of objects (e.g. TOMAL), sematically related or not Benton visual retention test If seriel: Counting recall of dots, span or score If associative: Items seen in a scene
VISUO-SPATIAL RECOGNITION	The ability to recognize spatial informations, i.e. location of visually presented single or multiple items among locations distractors: - immediately after presentation or after a delay - if associative: the ability to recognize associative informations, between visual and spatial	Location recognition test of objects Location recognition of an item in a context background If seriel: N-back location of a circle Triplets of shapes, order test If associative: Item-location relational memory of objecs Spatial change (location of items among a scene) Triplets of shapes, location test
VISUO-SPATIAL RECALL	The ability to recall spatial informations, i.e. location of visually presented single or multiple items: - immediately after presentation or after a delay	Maze memory: reproduce a path drawn a maze Dot matrix: recall the position of a dot in a matrice Odd-one-out shape If seriel: Sequence of coloured squares, spatial span (CANTAB) Sequence of taped blocks, spatial span or score (e.g. WMS-3) Location of blocks, Corsi block tapping test Order of presented shapes (e.g. visual sequential memory, TOMAL) If associative: Location of dots (i.e. memory for locations, TOMAL)

Supplementary Table 2 - Quality of assessment

Study	Question / objective sufficiently described?	Study design evident and appropriate?	Method of subject / comparison group selection or source of information / input variables described and appropriate?	Subject (and comparison group, if applicable) characteristics sufficiently described?	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Means of assessment reported?	Sample size appropriate?	Analytic methods described / justified and appropriate?	Some estimate of variance is reported for the main results?	Controlled for confounding?	Results reported in sufficient detail?	Conclusions supported by the results?	Total score	Percentage
Abbasy et al. (2018)	2	2	1	2	2	2	2	2	2	2	2	21	95%
Alloway et al. (2016)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Biscaldi et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Blair (2002)	2	2	2	2	2	0	2	2	2	2	2	20	91%
Bowler et al. (1997)	1	2	2	2	2	1	2	2	2	2	2	20	91%
Bowler et al. (2000)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Bowler et al. (2007)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Bowler et al. (2008)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Bowler et al. (2008a)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Bowler et al. (2010)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Bowler et al. (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Bowler, Gaigg, Gardiner (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Braden et al. (2017)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Chen et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Christ et al. (2017)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Cooper et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Cui et al. (2010)	1	2	2	2	2	0	2	2	2	2	2	19	86%
Funabiki & Shiwa (2018)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Gaigg, Gardiner &Bowler (2008)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Gaigg & Bowler (2008)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Gaigg et al. (2015)	2	2	2	2	2	0	2	2	2	2	2	20	91%

Garcia-Molina & Clemente-Estevan (2019)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Geurts et al. (2004)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Grainger, Williams, & Lind (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Grainger, Williams, & Lind (2016)	0	2	2	2	2	2	2	2	2	2	2	20	91%
Grainger, Williams, & Lind (2017)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Komeda et al., (2013)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Kouklari, Tsermentseli, & Monks (2018)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Li et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Lind, Bowler, & Raber (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
López, Leekam, & Arts (2008)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Loth, Gómez, & Happé (2011)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Mammarella, Cardillo, & Zoccante (2019)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Martínez et al., 2017)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Massand et al. (2013)	1	2	2	2	2	1	2	2	2	2	2	20	91%
Massand & Bowler (2015)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Matsuura et al. (2014)	2	2	2	2	2	0	2	2	2	2	2	20	91%
Mayer & Heaton (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Meyer, Gardiner, & Bowler (2014)	1	2	2	2	2	1	2	2	2	2	2	20	91%
Phelan et al. (2011)	1	2	2	2	2	1	2	2	2	2	2	20	91%
Poirier et al. 2011)	0	2	2	2	2	2	2	2	2	2	2	20	91%
Powell, Klinger, Klinger (2017)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Renner, Klinger, & Klinger (2000)	2	2	2	2	2	1	2	2	2	2	2	21	95%
Ring, Gaigg, & Bowler (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%

Ring, Gaigg, & Bowler (2016)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Ring et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Smith, Gardiner, & Bowler (2007)	2	2	2	2	2	0	2	2	2	2	2	20	91%
Souchay et al. (2013)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Trontel et al., (2013)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Trontel et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Urbain, Pang, & Taylor, (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Urbain et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Van Eylen et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Verté et al. (2005)	2	2	2	2	2	2	2	2	1	2	2	21	95%
Vogan et al. (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Williams, Goldstein, & Minshew (2005)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Williams, Goldstein, & Minshew (2006)	1	2	2	2	2	2	2	2	2	2	2	21	95%
Williams, Goldstein, & Minshew (2006b)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Williams, Bowler, & Jarrold (2012)	0	2	2	2	2	2	2	2	2	2	2	20	91%
Williams et al. (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Wojcik et al. (2014)	2	2	2	2	2	2	2	2	2	2	2	22	100%
Yamamoto & Masumoto(2018)	1	2	2	2	2	1	2	2	2	2	2	20	91%
Young & Brewer (2019)	0	2	2	2	2	2	2	2	2	2	2	20	91%
Yuk et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	22	100%

Note: 2 = Yes, 1 = Partial, 0 = No, N/A = Not applicable.

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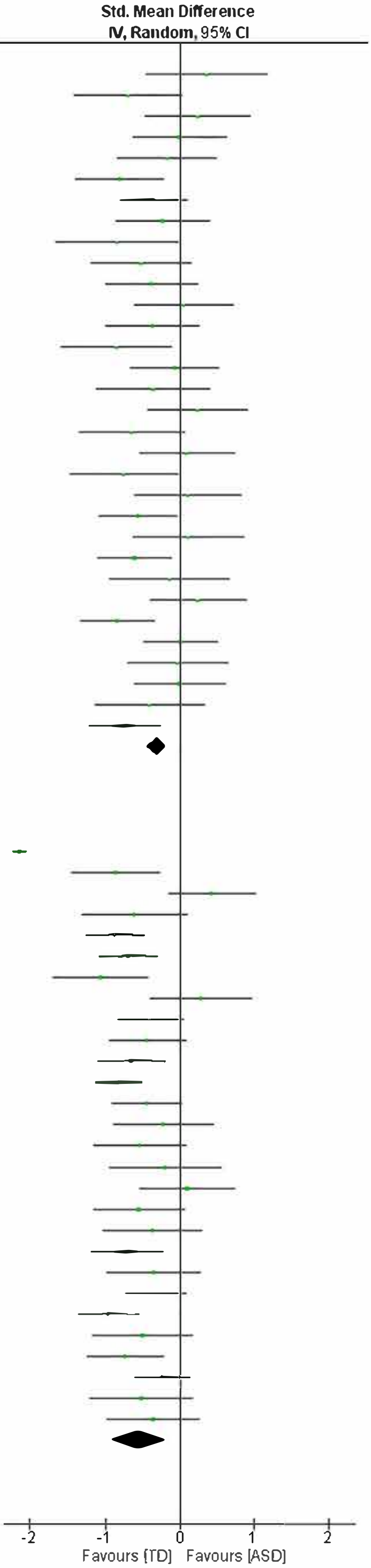
Supplementary Table 3 - Forest plot of subgroup comparison on LTM and STM performance between ASD people and TD controls

Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 LTM								
Blair 2002	29.47	3.29333333	12	28.22166667	3.39666667	12	2.1%	0.36 [-0.45, 1.17]
Bowler 1997	5.595	2.08	16	6.81	1.215	16	2.6%	-0.70 [-1.41, 0.02]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	2.6%	0.24 [-0.47, 0.95]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	3.2%	0.00 [-0.62, 0.62]
Bowler 2014	0.515	0.285	18	0.565	0.27	18	3.0%	-0.18 [-0.83, 0.48]
Cooper 2015	0.52	0.24	24	0.665	0.0745	24	3.5%	-0.80 [-1.39, -0.21]
Funabiki 2018	12.30333333	2.20666667	64	12.99666667	1.44	30	5.2%	-0.34 [-0.78, 0.09]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	3.2%	-0.23 [-0.85, 0.39]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	2.0%	-0.85 [-1.67, -0.02]
Grainger 2014	0.415	0.19	18	0.52	0.205	18	2.9%	-0.52 [-1.19, 0.15]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	3.3%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	2.9%	0.06 [-0.60, 0.72]
Lind 2014	0.67	0.24	20	0.75	0.19	20	3.2%	-0.36 [-0.99, 0.26]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	2.4%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	3.5%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	2.3%	-0.36 [-1.12, 0.40]
Massand 2013	0.68	0.16	22	0.64	0.17	14	2.8%	0.24 [-0.43, 0.91]
Massand 2015	0.575	0.25	15	0.715	0.17	18	2.6%	-0.65 [-1.36, 0.05]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	3.1%	0.09 [-0.54, 0.73]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	2.5%	-0.75 [-1.47, -0.03]
Phelan 2011	11.24	2.808	15	10.866	3.846	15	2.6%	0.11 [-0.61, 0.82]
Powell 2017	36.8	9.5	29	42.7	11.2	30	4.1%	-0.56 [-1.08, -0.04]
Renner 2000	0.59	0.09	14	0.58	0.085	14	2.4%	0.11 [-0.63, 0.85]
Ring 2018	0.72	0.18	37	0.82	0.14	31	4.5%	-0.61 [-1.09, -0.12]
Smith 2007	2.17	1.17	12	2.33	1.065	12	2.1%	-0.14 [-0.94, 0.66]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	3.1%	0.24 [-0.39, 0.88]
Trontel 2015	9.1	2.5	38	11.3	2.7	31	4.4%	-0.84 [-1.34, -0.34]
Williams 2005	10.48	2.62	29	10.455	2.81	34	4.4%	0.01 [-0.49, 0.50]
Williams 2012	13.69	3.46	17	13.79	2.78	17	2.8%	-0.03 [-0.70, 0.64]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	3.3%	0.00 [-0.60, 0.60]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	2.5%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	4.6%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**683**			**640**	**100.0%**	**-0.30 [-0.42, -0.17]**
Heterogeneity: Tau² = 0.03; Chi² = 40.98, df = 31 (P = 0.11); I² = 24%								
Test for overall effect: Z = 4.54 (P < 0.00001)								
1.1.2 STM								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	3.9%	-2.12 [-2.21, -2.03]
Alloway 2016	69.631	14.342	26	81.98	13.894	23	3.5%	-0.86 [-1.45, -0.27]
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	3.5%	0.43 [-0.15, 1.01]
Braden 2017	89.45	10.4	16	94.75	6.2	17	3.4%	-0.61 [-1.31, 0.09]
Chen 2016A	6.03666667	1.48666667	53	7.21666667	1.25666667	63	3.7%	-0.86 [-1.24, -0.48]
Chen 2016B	6.99	1.40333333	58	7.85666667	1.09	51	3.7%	-0.68 [-1.07, -0.29]
Christ 2017	13.2	2.85	22	16.25	2.8	22	3.5%	-1.06 [-1.70, -0.43]
Cui 2010	5.49875	1.485625	12	5.15875	1.000625	29	3.4%	0.29 [-0.39, 0.96]
Funabiki 2018	14.508	2.142	64	15.314	1.828	30	3.7%	-0.39 [-0.83, 0.05]
Garcia-Molina 2019	9.64	3.45	30	10.95	2.435	30	3.6%	-0.43 [-0.95, 0.08]
Geurts 2004	4.7	1.3	41	5.55	1.35	41	3.7%	-0.64 [-1.08, -0.19]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	3.8%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	3.6%	-0.44 [-0.91, 0.04]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	3.4%	-0.22 [-0.90, 0.45]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	3.5%	-0.54 [-1.16, 0.08]
Matsuura 2014	0.33	1.105	11	0.565	1.235	19	3.4%	-0.19 [-0.94, 0.55]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	3.5%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	3.5%	-0.55 [-1.15, 0.06]
Ring 2016	0.5125	0.2325	18	0.595	0.2075	18	3.5%	-0.37 [-1.03, 0.29]
Trontel 2015	8.32857143	3.3	38	10.55714286	2.87142857	31	3.6%	-0.71 [-1.20, -0.22]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	3.5%	-0.35 [-0.98, 0.27]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	3.7%	-0.31 [-0.71, 0.08]
Verté 2005	4.65	1.4	61	5.85	1.05	47	3.7%	-0.95 [-1.35, -0.54]
Vogan 2014	99.118	18.14	19	108.728	19.632	17	3.4%	-0.50 [-1.16, 0.17]
Williams 2005	9.55	3.245	29	11.585	2.19	34	3.6%	-0.74 [-1.25, -0.22]
Williams 2006	10.05	3.09	56	10.73	2.84	56	3.7%	-0.23 [-0.60, 0.14]
Williams 2014	5.985	1.215	17	6.535	0.81	17	3.4%	-0.52 [-1.21, 0.16]
Yuk 2018	204	37.01	19	216.64	32.71	22	3.5%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**2408**			**2369**	**100.0%**	**-0.53 [-0.90, -0.16]**
Heterogeneity: Tau² = 0.93; Chi² = 607.91, df = 27 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.79 (P = 0.005)								

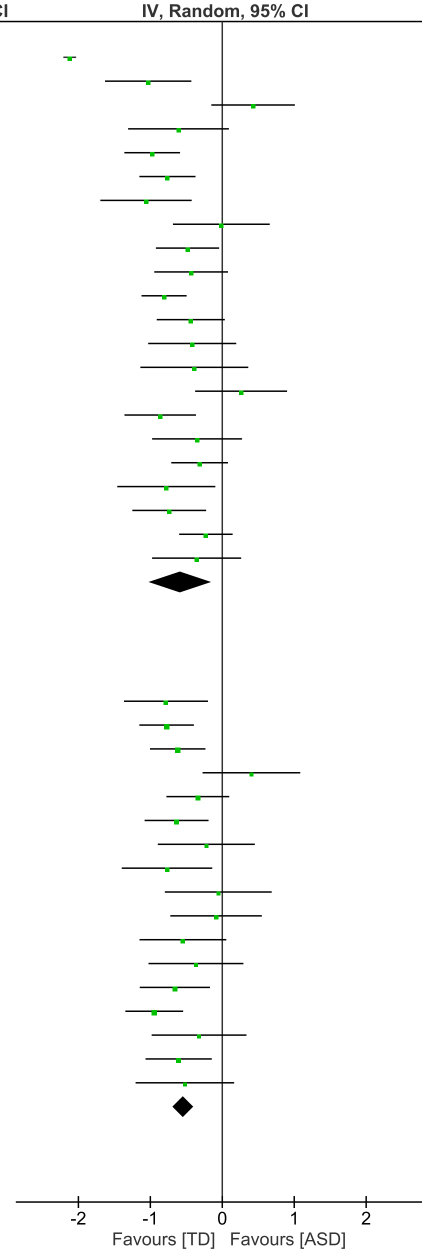


Test for subgroup differences: Chi² = 1.34, df = 1 (P = 0.25), I² = 25.6%

Supplementary Table 4 - Forest plot of subgroup comparison on STM performance according to additional memory control, between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
2.1.1 Plus additional cognitive control								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	4.9%	-2.12 [-2.21, -2.03]
Alloway 2016	45.7425	11.8225	26	57.0275	9.46	23	4.5%	-1.03 [-1.63, -0.43]
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	4.5%	0.43 [-0.15, 1.01]
Braden 2017	89.45	10.4	16	94.75	6.2	17	4.3%	-0.61 [-1.31, 0.09]
Chen 2016A	4.44	1.57	53	6.05	1.7	63	4.7%	-0.97 [-1.36, -0.59]
Chen 2016B	5.7	1.71	58	6.92	1.44	51	4.7%	-0.76 [-1.15, -0.37]
Christ 2017	13.2	2.85	22	16.25	2.8	22	4.4%	-1.06 [-1.70, -0.43]
Cui 2010	2.195	0.73	12	2.20375	0.62375	29	4.4%	-0.01 [-0.69, 0.66]
Funabiki 2018	8.36	1.86	64	9.235	1.645	30	4.7%	-0.48 [-0.92, -0.04]
Garcia-Molina 2019	9.64	3.45	30	10.95	2.435	30	4.6%	-0.43 [-0.95, 0.08]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	4.8%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	4.6%	-0.44 [-0.91, 0.04]
Martinez 2017	4.31	0.935	21	4.76	1.165	21	4.5%	-0.42 [-1.03, 0.19]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	4.3%	-0.39 [-1.14, 0.36]
Mayer 2014	8.37	2.54	19	7.63	2.98	19	4.4%	0.26 [-0.38, 0.90]
Trontel 2015	8.35	2.75	38	10.6	2.35	31	4.6%	-0.86 [-1.36, -0.37]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	4.4%	-0.35 [-0.98, 0.27]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	4.7%	-0.31 [-0.71, 0.08]
Vogan 2014	98.5	17.28	19	112.97	19.155	17	4.4%	-0.78 [-1.46, -0.10]
Williams 2005	9.55	3.245	29	11.585	2.19	34	4.6%	-0.74 [-1.25, -0.22]
Williams 2006	10.05	3.09	56	10.73	2.84	56	4.7%	-0.23 [-0.60, 0.14]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.4%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**2232**			**2207**	**100.0%**	**-0.58 [-1.01, -0.14]**
Heterogeneity: Tau² = 0.99; Chi² = 528.36, df = 21 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.62 (P = 0.009)								
2.1.2 Without additional cognitive control								
Alloway 2016	85.55666667	16.02166667	26	98.615	16.85	23	5.1%	-0.78 [-1.37, -0.20]
Chen 2016A	6.835	1.445	53	7.8	1.035	63	9.6%	-0.77 [-1.15, -0.39]
Chen 2016B	7.635	1.25	58	8.325	0.915	51	9.4%	-0.62 [-1.00, -0.23]
Cui 2010	8.8025	2.24125	12	8.11375	1.3775	29	4.0%	0.41 [-0.27, 1.08]
Funabiki 2018	18.60666667	2.33	64	19.36666667	1.95	30	7.9%	-0.34 [-0.78, 0.10]
Geurts 2004	4.7	1.3	41	5.55	1.35	41	7.7%	-0.64 [-1.08, -0.19]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	4.0%	-0.22 [-0.90, 0.45]
Martinez 2017	5.14	0.85	21	6	1.3	21	4.5%	-0.77 [-1.40, -0.14]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	3.4%	-0.06 [-0.80, 0.69]
Mayer 2014	11.32	2.43	19	11.53	2.32	19	4.4%	-0.09 [-0.72, 0.55]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.8%	-0.55 [-1.15, 0.06]
Ring 2016	0.5125	0.2325	18	0.595	0.2075	18	4.2%	-0.37 [-1.03, 0.29]
Trontel 2015	8.32	3.52	38	10.54	3.08	31	6.7%	-0.66 [-1.15, -0.17]
Vertė 2005	4.65	1.4	61	5.85	1.05	47	8.9%	-0.95 [-1.35, -0.54]
Vogan 2014	99.53	18.71333333	19	105.9	19.95	17	4.2%	-0.32 [-0.98, 0.34]
Williams 2006	8.74	3.27	38	10.64	2.925	38	7.3%	-0.61 [-1.07, -0.15]
Williams 2014	5.985	1.215	17	6.535	0.81	17	3.9%	-0.52 [-1.21, 0.16]
Subtotal (95% CI)			**535**			**503**	**100.0%**	**-0.53 [-0.68, -0.38]**
Heterogeneity: Tau² = 0.02; Chi² = 20.56, df = 16 (P = 0.20); I² = 22%								
Test for overall effect: Z = 7.11 (P < 0.00001)								

Std. Mean Difference
IV, Random, 95% CI

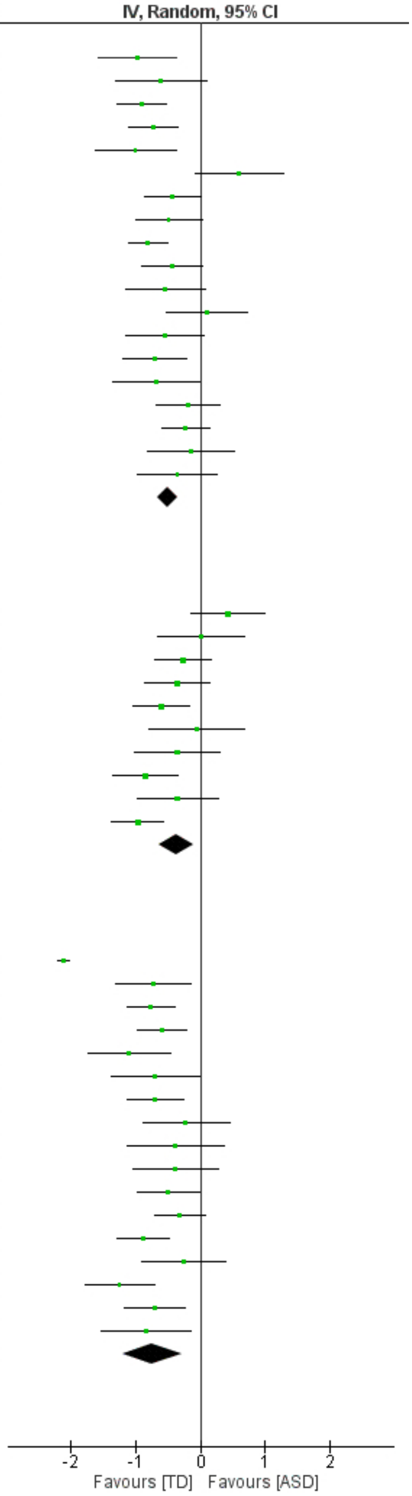


Test for subgroup differences: Chi² = 0.04, df = 1 (P = 0.85), I² = 0%

Supplementary Table 5 - Forest plot of subgroup comparison on STM performance according to type of material, used during the encoding, between ASD people and TD controls.

	ASD			TD				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
4.1.1 Verbal								
Alloway 2016	59.16166667	13.23333333	26	71.7	11.88833333	23	4.5%	-0.98 [-1.57, -0.38]
Braden 2017	89.45	10.4	16	94.75	6.2	17	3.7%	-0.61 [-1.31, 0.09]
Chen 2016A	6.035	1.39	53	7.255	1.29	63	7.2%	-0.91 [-1.29, -0.52]
Chen 2016B	6.905	1.355	58	7.795	1.015	51	7.1%	-0.73 [-1.12, -0.34]
Christ 2017	13.6	2.4	22	16.1	2.5	22	4.2%	-1.00 [-1.63, -0.37]
Cui 2010	7.21875	1.77125	12	6.3375	1.28875	29	3.8%	0.60 [-0.09, 1.29]
Funabiki 2018	8.7725	1.89	64	9.585	1.745	30	6.4%	-0.44 [-0.87, 0.00]
Garcia-Molina 2019	9.69	3.64	30	11.33	2.93	30	5.4%	-0.49 [-1.00, 0.02]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	8.3%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	5.9%	-0.44 [-0.91, 0.04]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.3%	-0.54 [-1.16, 0.08]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	4.2%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.5%	-0.55 [-1.15, 0.06]
Trontel 2015	7.9	3.025	38	9.975	2.775	31	5.7%	-0.70 [-1.19, -0.21]
Vogan 2014	101.53	18.03	19	113.98	17.98333333	17	3.9%	-0.68 [-1.35, -0.00]
Williams 2005	10.86	3.07	29	11.38	2.24	34	5.6%	-0.19 [-0.69, 0.30]
Williams 2006	10.05	3.09	56	10.73	2.84	56	7.3%	-0.23 [-0.60, 0.14]
Williams 2014	6.705	1.115	17	6.84	0.735	17	3.9%	-0.14 [-0.81, 0.53]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.3%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**632**			**634**	**100.0%**	**-0.51 [-0.67, -0.35]**
Heterogeneity: Tau² = 0.06; Chi² = 33.20, df = 18 (P = 0.02); I² = 46%								
Test for overall effect: Z = 6.21 (P < 0.00001)								
4.1.2 Visual								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	9.5%	0.43 [-0.15, 1.01]
Cui 2010	4.0225	1.7125	12	4.0075	0.88	29	8.2%	0.01 [-0.66, 0.69]
Funabiki 2018	37.45	3.15	64	38.23	2.16	30	11.9%	-0.27 [-0.70, 0.17]
Garcia-Molina 2019	9.59	3.26	30	10.57	1.94	30	10.6%	-0.36 [-0.87, 0.15]
Geurts 2004	5	1.7	41	6.1	1.9	41	11.7%	-0.60 [-1.05, -0.16]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	7.4%	-0.06 [-0.80, 0.69]
Ring 2016	0.525	0.245	18	0.61	0.225	18	8.4%	-0.35 [-1.01, 0.31]
Trontel 2015	8.45	3.25	38	11.05	2.7	31	10.8%	-0.85 [-1.35, -0.36]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	8.9%	-0.35 [-0.98, 0.27]
Verté 2005	5	1.9	61	6.7	1.5	47	12.5%	-0.97 [-1.37, -0.57]
Subtotal (95% CI)			**313**			**298**	**100.0%**	**-0.38 [-0.64, -0.11]**
Heterogeneity: Tau² = 0.11; Chi² = 22.05, df = 9 (P = 0.009); I² = 59%								
Test for overall effect: Z = 2.78 (P = 0.005)								
4.1.3 Visuo-Spatial								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	6.4%	-2.12 [-2.21, -2.03]
Alloway 2016	85.335	16.005	26	97.4	16.9025	23	5.8%	-0.72 [-1.30, -0.14]
Chen 2016A	6.04	1.68	53	7.14	1.19	63	6.1%	-0.76 [-1.14, -0.38]
Chen 2016B	7.16	1.5	58	7.98	1.24	51	6.1%	-0.59 [-0.97, -0.20]
Christ 2017	12.8	3.3	22	16.4	3.1	22	5.7%	-1.10 [-1.74, -0.47]
Cui 2010	3.535	0.6875	12	3.9525	0.545	29	5.6%	-0.70 [-1.39, -0.00]
Geurts 2004	4.4	0.9	41	5	0.8	41	6.0%	-0.70 [-1.14, -0.25]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	5.6%	-0.22 [-0.90, 0.45]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	5.5%	-0.39 [-1.14, 0.36]
Ring 2016	0.5	0.22	18	0.58	0.19	18	5.7%	-0.38 [-1.04, 0.28]
Trontel 2015	9.8	4.5	38	11.9	3.6	31	6.0%	-0.50 [-0.99, -0.02]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	6.1%	-0.31 [-0.71, 0.08]
Verté 2005	4.3	0.9	61	5	0.6	47	6.1%	-0.89 [-1.29, -0.49]
Vogan 2014	95.5	18.305	19	100.85	22.105	17	5.7%	-0.26 [-0.92, 0.40]
Williams 2005	8.24	3.42	29	11.79	2.14	34	5.9%	-1.25 [-1.80, -0.71]
Williams 2006	8.61	3	38	10.89	3.35	38	6.0%	-0.71 [-1.17, -0.25]
Williams 2014	5.265	1.315	17	6.23	0.885	17	5.6%	-0.84 [-1.55, -0.14]
Subtotal (95% CI)			**2050**			**2007**	**100.0%**	**-0.74 [-1.20, -0.28]**
Heterogeneity: Tau² = 0.87; Chi² = 357.04, df = 16 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 3.14 (P = 0.002)								

Std. Mean Difference
IV, Random, 95% CI

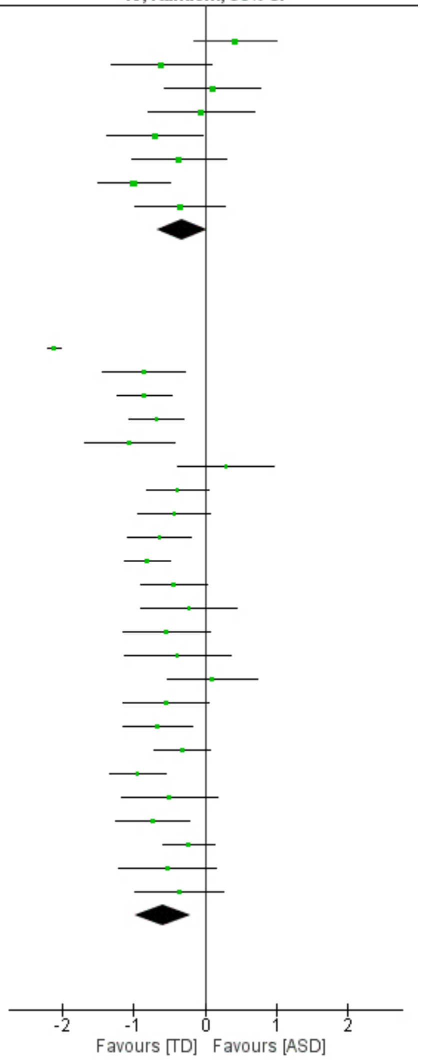


Test for subgroup differences: Chi² = 1.86, df = 2 (P = 0.39), I² = 0%

Supplementary Table 6 - Forest plot of subgroup comparison on STM performance according to type of retrieval between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
6.1.1 Recognition								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	13.5%	0.43 [-0.15, 1.01]
Braden 2017	89.45	10.4	16	94.75	6.2	17	11.6%	-0.61 [-1.31, 0.09]
Cui 2010	0.77333333	0.11666667	12	0.76	0.13166667	29	12.0%	0.10 [-0.57, 0.78]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	11.0%	-0.06 [-0.80, 0.69]
Poirier 2011	0.68	0.21	18	0.8	0.11	18	12.0%	-0.70 [-1.38, -0.02]
Ring 2016	0.5125	0.2325	18	0.595	0.2075	18	12.2%	-0.37 [-1.03, 0.29]
Trontel 2015	9.8	3	38	12.7	2.7	31	14.9%	-1.00 [-1.50, -0.49]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	12.8%	-0.35 [-0.98, 0.27]
Subtotal (95% CI)			**151**			**185**	**100.0%**	**-0.33 [-0.68, 0.02]**
Heterogeneity: Tau² = 0.15; Chi² = 17.16, df = 7 (P = 0.02); I² = 59%								
Test for overall effect: Z = 1.82 (P = 0.07)								
6.1.2 Free recall								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	4.5%	-2.12 [-2.21, -2.03]
Alloway 2016	69.631	14.342	26	81.98	13.894	23	4.1%	-0.86 [-1.45, -0.27]
Chen 2016A	6.03666667	1.48666667	53	7.21666667	1.25666667	63	4.3%	-0.86 [-1.24, -0.48]
Chen 2016B	6.99	1.40333333	58	7.85666667	1.09	51	4.3%	-0.68 [-1.07, -0.29]
Christ 2017	13.2	2.85	22	16.25	2.8	22	4.0%	-1.06 [-1.70, -0.43]
Cui 2010	8.334	2.307	12	7.798	1.522	29	4.0%	0.30 [-0.38, 0.97]
Funabiki 2018	14.508	2.142	64	15.314	1.828	30	4.3%	-0.39 [-0.83, 0.05]
Garcia-Molina 2019	9.64	3.45	30	10.95	2.435	30	4.2%	-0.43 [-0.95, 0.08]
Geurts 2004	4.7	1.3	41	5.55	1.35	41	4.3%	-0.64 [-1.08, -0.19]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	4.4%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	4.2%	-0.44 [-0.91, 0.04]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	4.0%	-0.22 [-0.90, 0.45]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.1%	-0.54 [-1.16, 0.08]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	3.9%	-0.39 [-1.14, 0.36]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	4.0%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.1%	-0.55 [-1.15, 0.06]
Trontel 2015	8.08333333	3.35	38	10.2	2.9	31	4.2%	-0.66 [-1.15, -0.18]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	4.3%	-0.31 [-0.71, 0.08]
Verté 2005	4.65	1.4	61	5.85	1.05	47	4.3%	-0.95 [-1.35, -0.54]
Vogan 2014	99.118	18.14	19	108.728	19.632	17	4.0%	-0.50 [-1.16, 0.17]
Williams 2005	9.55	3.245	29	11.585	2.19	34	4.2%	-0.74 [-1.25, -0.22]
Williams 2006	10.05	3.09	56	10.73	2.84	56	4.3%	-0.23 [-0.60, 0.14]
Williams 2014	5.985	1.215	17	6.535	0.81	17	4.0%	-0.52 [-1.21, 0.16]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.1%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**2336**			**2281**	**100.0%**	**-0.59 [-0.98, -0.19]**
Heterogeneity: Tau² = 0.91; Chi² = 541.22, df = 23 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.90 (P = 0.004)								

Std. Mean Difference
IV, Random, 95% CI

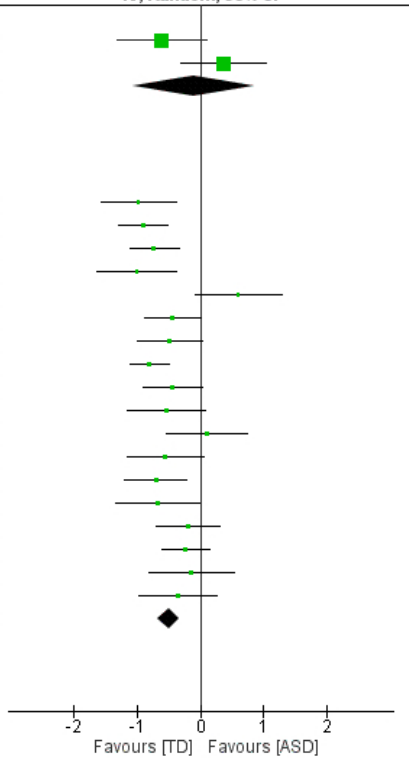


Test for subgroup differences: Chi² = 0.90, df = 1 (P = 0.34), I² = 0%

Supplementary Table 7 - Forest plot of subgroup comparison on verbal STM performance according to type of retrieval between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
8.1.1 Recognition								
Cui 2010	89.45	10.4	16	94.75	6.2	17	49.6%	-0.61 [-1.31, 0.09]
Braden 2017	0.79	0.135	12	0.74	0.13	29	50.4%	0.37 [-0.31, 1.05]
Subtotal (95% CI)			**28**			**46**	**100.0%**	**-0.11 [-1.08, 0.85]**
Heterogeneity: Tau² = 0.36; Chi² = 3.90, df = 1 (P = 0.05); I² = 74%								
Test for overall effect: Z = 0.23 (P = 0.82)								
8.1.2 Free recall								
Yuk 2018	59.16166667	13.23333333	26	71.7	11.88833333	23	4.7%	-0.98 [-1.57, -0.38]
Williams 2014	6.035	1.39	53	7.255	1.29	63	7.3%	-0.91 [-1.29, -0.52]
Williams 2006	6.905	1.355	58	7.795	1.015	51	7.3%	-0.73 [-1.12, -0.34]
Williams 2005	13.6	2.4	22	16.1	2.5	22	4.4%	-1.00 [-1.63, -0.37]
Vogan 2014	9.36166667	2.31666667	12	8.20333333	1.675	29	4.0%	0.60 [-0.08, 1.29]
Trontel 2015	8.7725	1.89	64	9.585	1.745	30	6.6%	-0.44 [-0.87, 0.00]
Poirier 2011	9.69	3.64	30	11.33	2.93	30	5.6%	-0.49 [-1.00, 0.02]
Mayer 2014	11.33	3.09	79	13.97	3.38	91	8.4%	-0.81 [-1.12, -0.50]
Martinez 2017	8.705	3.97	32	10.165	2.62	39	6.1%	-0.44 [-0.91, 0.04]
Li 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.6%	-0.54 [-1.16, 0.08]
Kouklari 2017	9.845	2.485	19	9.58	2.65	19	4.4%	0.10 [-0.54, 0.74]
Garcia-Molina 2019	0.6	0.155	22	0.685	0.15	22	4.7%	-0.55 [-1.15, 0.06]
Funabiki 2018	7.9	3.025	38	9.975	2.775	31	5.9%	-0.70 [-1.19, -0.21]
Cui 2010	101.53	18.03	19	113.98	17.98333333	17	4.1%	-0.68 [-1.35, -0.00]
Christ 2017	10.86	3.07	29	11.38	2.24	34	5.8%	-0.19 [-0.69, 0.30]
Chen 2016B	10.05	3.09	56	10.73	2.84	56	7.5%	-0.23 [-0.60, 0.14]
Chen 2016A	6.705	1.115	17	6.84	0.735	17	4.1%	-0.14 [-0.81, 0.53]
Alloway 2016	204	37.01	19	216.64	32.71	22	4.5%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**616**			**617**	**100.0%**	**-0.50 [-0.67, -0.34]**
Heterogeneity: Tau² = 0.06; Chi² = 33.25, df = 17 (P = 0.01); I² = 49%								
Test for overall effect: Z = 5.89 (P < 0.00001)								

Std. Mean Difference
IV, Random, 95% CI

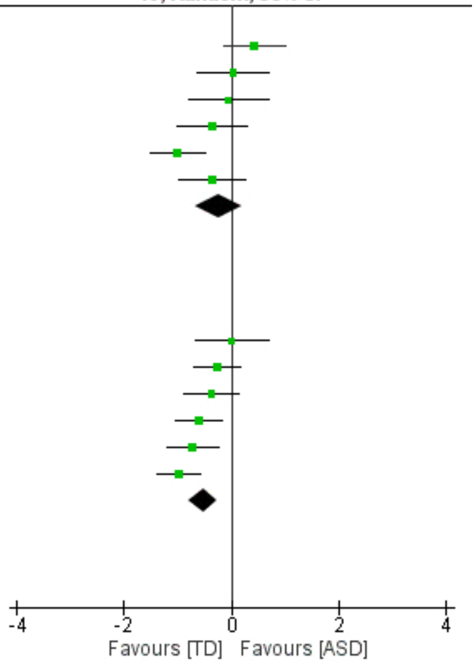


Test for subgroup differences: Chi² = 0.61, df = 1 (P = 0.44), I² = 0%

Supplementary Table 8 - Forest plot of subgroup comparison on visual STM performance according to type of retrieval between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
8.2.1 Recognition								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	17.6%	0.43 [-0.15, 1.01]
Cui 2010	0.795	0.11	12	0.79	0.135	29	15.9%	0.04 [-0.63, 0.71]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	14.7%	-0.06 [-0.80, 0.69]
Ring 2016	0.525	0.245	18	0.61	0.225	18	16.1%	-0.35 [-1.01, 0.31]
Trontel 2015	9.8	3	38	12.7	2.7	31	19.0%	-1.00 [-1.50, -0.49]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	16.7%	-0.35 [-0.98, 0.27]
Subtotal (95% CI)			**117**			**150**	**100.0%**	**-0.23 [-0.67, 0.21]**
Heterogeneity: Tau² = 0.20; Chi² = 14.83, df = 5 (P = 0.01); I² = 66%								
Test for overall effect: Z = 1.04 (P = 0.30)								
8.2.2 Free recall								
Cui 2010	7.25	3.315	12	7.225	1.625	29	11.1%	0.01 [-0.66, 0.68]
Funabiki 2018	37.45	3.15	64	38.23	2.16	30	18.5%	-0.27 [-0.70, 0.17]
Garcia-Molina 2019	9.59	3.26	30	10.57	1.94	30	15.7%	-0.36 [-0.87, 0.15]
Geurts 2004	5	1.7	41	6.1	1.9	41	18.2%	-0.60 [-1.05, -0.16]
Trontel 2015	7.1	3.5	38	9.4	2.7	31	16.4%	-0.72 [-1.21, -0.23]
Verté 2005	5	1.9	61	6.7	1.5	47	19.9%	-0.97 [-1.37, -0.57]
Subtotal (95% CI)			**246**			**208**	**100.0%**	**-0.53 [-0.80, -0.26]**
Heterogeneity: Tau² = 0.05; Chi² = 9.51, df = 5 (P = 0.09); I² = 47%								
Test for overall effect: Z = 3.82 (P = 0.0001)								

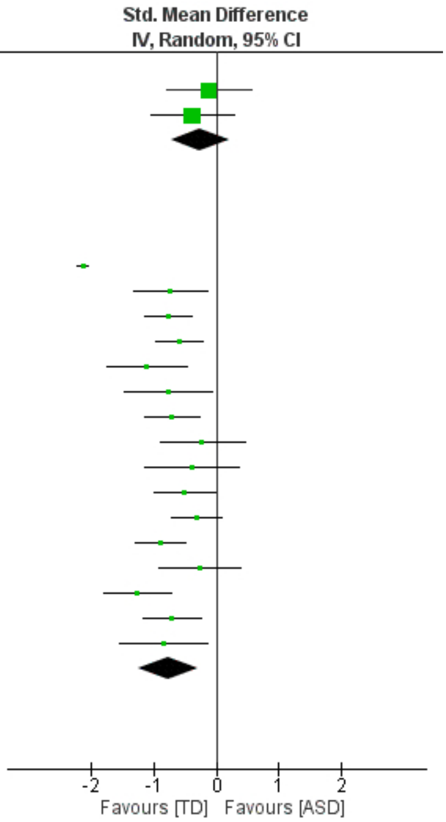
Std. Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 1.26, df = 1 (P = 0.26), I² = 20.5%

Supplementary Table 9 - Forest plot of subgroup comparison on visuo-spatial STM performance according to type of retrieval between ASD people and TD controls

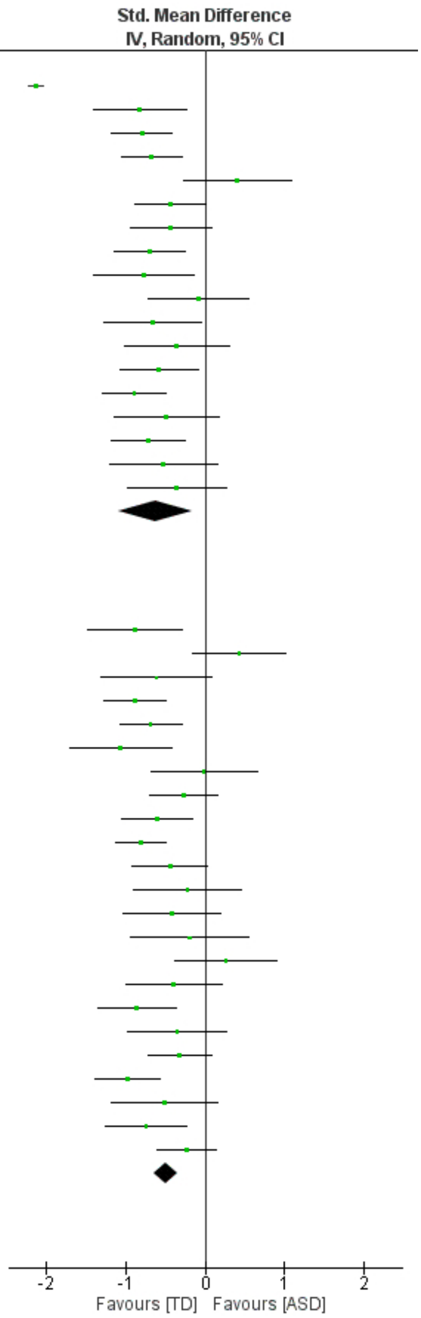
	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
8.3.1 Recognition								
Cui 2010	0.735	0.105	12	0.75	0.13	29	49.0%	-0.12 [-0.79, 0.55]
Ring 2016	0.5	0.22	18	0.58	0.19	18	51.0%	-0.38 [-1.04, 0.28]
Subtotal (95% CI)			**30**			**47**	**100.0%**	**-0.25 [-0.72, 0.22]**
Heterogeneity: Tau² = 0.00; Chi² = 0.30, df = 1 (P = 0.59); I² = 0%								
Test for overall effect: Z = 1.05 (P = 0.29)								
8.3.2 Free recall								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	6.8%	-2.12 [-2.21, -2.03]
Alloway 2016	85.335	16.005	26	97.4	16.9025	23	6.2%	-0.72 [-1.30, -0.14]
Chen 2016A	6.04	1.68	53	7.14	1.19	63	6.5%	-0.76 [-1.14, -0.38]
Chen 2016B	7.16	1.5	58	7.98	1.24	51	6.5%	-0.59 [-0.97, -0.20]
Christ 2017	12.8	3.3	22	16.4	3.1	22	6.1%	-1.10 [-1.74, -0.47]
Cui 2010	6.335	1.27	12	7.155	0.96	29	5.9%	-0.76 [-1.46, -0.07]
Geurts 2004	4.4	0.9	41	5	0.8	41	6.4%	-0.70 [-1.14, -0.25]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	6.0%	-0.22 [-0.90, 0.45]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	5.8%	-0.39 [-1.14, 0.36]
Trontel 2015	9.8	4.5	38	11.9	3.6	31	6.3%	-0.50 [-0.99, -0.02]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	6.5%	-0.31 [-0.71, 0.08]
Verté 2005	4.3	0.9	61	5	0.6	47	6.5%	-0.89 [-1.29, -0.49]
Vogan 2014	95.5	18.305	19	100.85	22.105	17	6.0%	-0.26 [-0.92, 0.40]
Williams 2005	8.24	3.42	29	11.79	2.14	34	6.2%	-1.25 [-1.80, -0.71]
Williams 2006	8.61	3	38	10.89	3.35	38	6.4%	-0.71 [-1.17, -0.25]
Williams 2014	5.265	1.315	17	6.23	0.885	17	5.9%	-0.84 [-1.55, -0.14]
Subtotal (95% CI)			**2032**			**1989**	**100.0%**	**-0.77 [-1.24, -0.29]**
Heterogeneity: Tau² = 0.86; Chi² = 341.86, df = 15 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 3.17 (P = 0.002)								



Test for subgroup differences: Chi² = 2.27, df = 1 (P = 0.13), I² = 56.0%

Supplementary Table 10 - Forest plot of subgroup comparison on serial and no serial STM performance between ASD people and TD controls

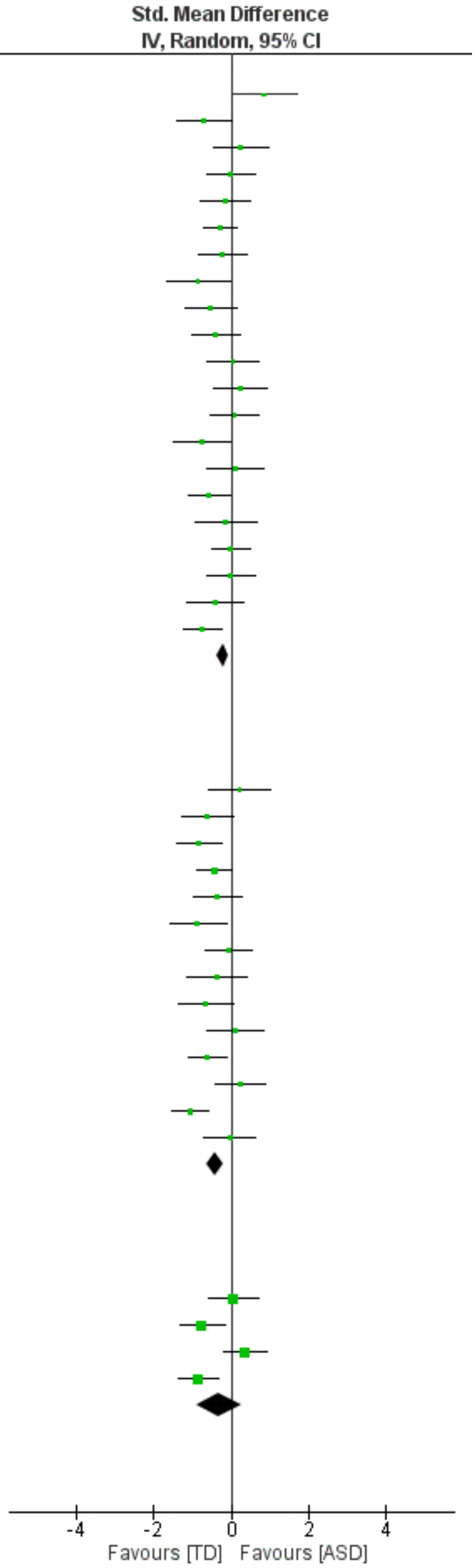
Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
10.2.1 Serial memory								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	6.0%	-2.12 [-2.21, -2.03]
Alloway 2016	66.315	13.1175	26	77.2475	13.0625	23	5.5%	-0.82 [-1.41, -0.24]
Chen 2016A	7.63	1.21	53	8.46	0.88	63	5.8%	-0.79 [-1.17, -0.41]
Chen 2016B	8.11	1	58	8.67	0.59	51	5.8%	-0.67 [-1.05, -0.28]
Cui 2010	8.8025	2.24125	12	8.11375	1.3775	29	5.3%	0.41 [-0.27, 1.08]
Funabiki 2018	8.7725	1.89	64	9.585	1.745	30	5.7%	-0.44 [-0.87, 0.00]
Garcia-Molina 2019	9.64	3.45	30	10.95	2.435	30	5.6%	-0.43 [-0.95, 0.08]
Geurts 2004	4.4	0.9	41	5	0.8	41	5.7%	-0.70 [-1.14, -0.25]
Martinez 2017	5.14	0.85	21	6	1.3	21	5.4%	-0.77 [-1.40, -0.14]
Mayer 2014	11.32	2.43	19	11.53	2.32	19	5.4%	-0.09 [-0.72, 0.55]
Poirier 2011	0.51	0.19	22	0.63	0.17	22	5.4%	-0.65 [-1.26, -0.05]
Ring 2016	0.5	0.26	18	0.58	0.17	18	5.4%	-0.36 [-1.02, 0.30]
Trontel 2015	7.45	3.3	38	9.35	3.2	31	5.6%	-0.58 [-1.06, -0.09]
Verté 2005	4.3	0.9	61	5	0.6	47	5.7%	-0.89 [-1.29, -0.49]
Vogan 2014	101.585	18.78	19	110.675	18.18	17	5.3%	-0.48 [-1.15, 0.18]
Williams 2006	8.61	3	38	10.89	3.35	38	5.7%	-0.71 [-1.17, -0.25]
Williams 2014	5.985	1.215	17	6.535	0.81	17	5.3%	-0.52 [-1.21, 0.16]
Yuk 2018	204	37.01	19	216.64	32.71	22	5.4%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**2096**			**2009**	**100.0%**	**-0.62 [-1.09, -0.15]**
Heterogeneity: Tau² = 0.95; Chi² = 404.82, df = 17 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.60 (P = 0.009)								
10.2.2 No serial memory								
Alloway 2016	71.84166667	15.15833333	26	85.135	14.44833333	23	3.8%	-0.88 [-1.47, -0.29]
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	3.9%	0.43 [-0.15, 1.01]
Braden 2017	89.45	10.4	16	94.75	6.2	17	3.1%	-0.61 [-1.31, 0.09]
Chen 2016A	5.24	1.625	53	6.595	1.445	63	5.7%	-0.88 [-1.26, -0.50]
Chen 2016B	6.43	1.605	58	7.45	1.34	51	5.7%	-0.68 [-1.07, -0.29]
Christ 2017	13.2	2.85	22	16.25	2.8	22	3.5%	-1.06 [-1.70, -0.43]
Cui 2010	2.195	0.73	12	2.20375	0.62375	29	3.2%	-0.01 [-0.69, 0.66]
Funabiki 2018	37.45	3.15	64	38.23	2.16	30	5.2%	-0.27 [-0.70, 0.17]
Geurts 2004	5	1.7	41	6.1	1.9	41	5.1%	-0.60 [-1.05, -0.16]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	6.5%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	4.8%	-0.44 [-0.91, 0.04]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	3.2%	-0.22 [-0.90, 0.45]
Martinez 2017	4.31	0.935	21	4.76	1.165	21	3.6%	-0.42 [-1.03, 0.19]
Matsuura 2014	0.33	1.105	11	0.565	1.235	19	2.8%	-0.19 [-0.94, 0.55]
Mayer 2014	8.37	2.54	19	7.63	2.98	19	3.4%	0.26 [-0.38, 0.90]
Poirier 2011	0.69	0.12	22	0.74	0.13	22	3.7%	-0.39 [-0.99, 0.20]
Trontel 2015	8.4	3	38	10.825	2.525	31	4.6%	-0.86 [-1.35, -0.36]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	3.5%	-0.35 [-0.98, 0.27]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	5.6%	-0.31 [-0.71, 0.08]
Verté 2005	5	1.9	61	6.7	1.5	47	5.5%	-0.97 [-1.37, -0.57]
Vogan 2014	97.47333333	17.71333333	19	107.43	20.6	17	3.3%	-0.51 [-1.18, 0.16]
Williams 2005	9.55	3.245	29	11.585	2.19	34	4.4%	-0.74 [-1.25, -0.22]
Williams 2006	10.05	3.09	56	10.73	2.84	56	5.9%	-0.23 [-0.60, 0.14]
Subtotal (95% CI)			**784**			**792**	**100.0%**	**-0.50 [-0.65, -0.35]**
Heterogeneity: Tau² = 0.06; Chi² = 44.03, df = 22 (P = 0.004); I² = 50%								
Test for overall effect: Z = 6.53 (P < 0.00001)								



Test for subgroup differences: Chi² = 0.23, df = 1 (P = 0.63), I² = 0%

Supplementary Table 11 - Forest plot of subgroup comparison on LTM performance according to type of material, used during the encoding, between ASD people and TD controls

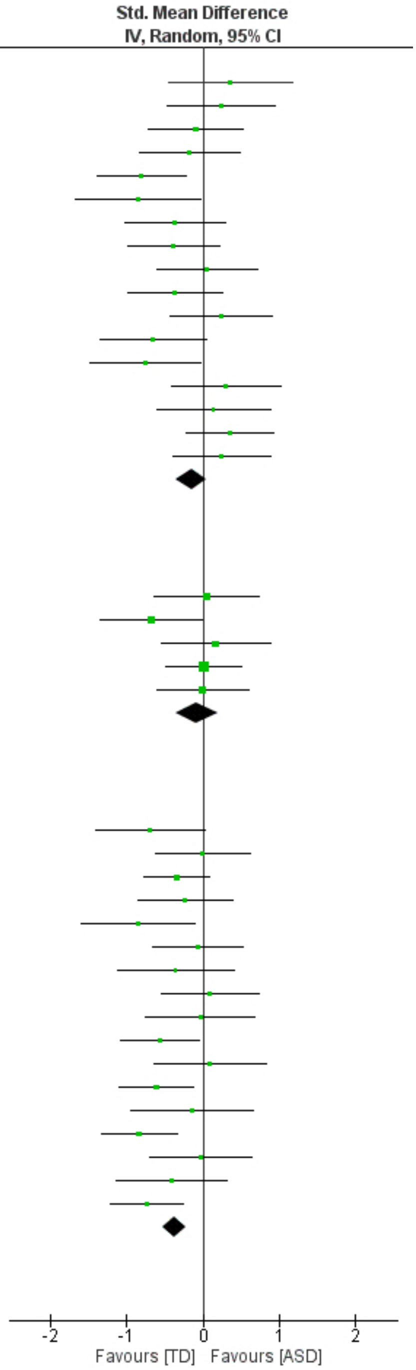
	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
3.1.1 Verbal								
Blair 2002	48	2.8	12	44.25	5.26	12	3.1%	0.86 [0.02, 1.70]
Bowler 1997	5.595	2.08	16	6.81	1.215	16	4.0%	-0.70 [-1.41, 0.02]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	4.1%	0.24 [-0.47, 0.95]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	5.0%	0.00 [-0.62, 0.62]
Bowler 2015	0.65	0.23	18	0.68	0.19	18	4.6%	-0.14 [-0.79, 0.52]
Funabiki 2018	10.465	1.65	64	10.88	1.29	30	7.8%	-0.27 [-0.70, 0.17]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	4.9%	-0.23 [-0.85, 0.39]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	3.2%	-0.85 [-1.67, -0.02]
Grainger 2014	0.415	0.19	18	0.52	0.205	18	4.5%	-0.52 [-1.19, 0.15]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	5.0%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	4.5%	0.06 [-0.60, 0.72]
Massand 2013	0.68	0.16	22	0.64	0.17	14	4.4%	0.24 [-0.43, 0.91]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	4.8%	0.09 [-0.54, 0.73]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	3.9%	-0.75 [-1.47, -0.03]
Phelan 2011	11.24	2.808	15	10.866	3.846	15	4.0%	0.11 [-0.61, 0.82]
Powell 2017	36.8	9.5	29	42.7	11.2	30	6.3%	-0.56 [-1.08, -0.04]
Smith 2007	2.17	1.17	12	2.33	1.065	12	3.3%	-0.14 [-0.94, 0.66]
Williams 2005	10.48	2.62	29	10.455	2.81	34	6.7%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	5.1%	0.00 [-0.60, 0.60]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	3.9%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	7.0%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**446**			**416**	**100.0%**	**-0.21 [-0.38, -0.05]**
Heterogeneity: Tau² = 0.04; Chi² = 27.37, df = 20 (P = 0.13); I² = 27%								
Test for overall effect: Z = 2.58 (P = 0.010)								
3.1.2 Visual								
Blair 2002	25.764	3.392	12	25.016	3.024	12	5.2%	0.22 [-0.58, 1.03]
Bowler 2014	0.77	0.23	18	0.89	0.15	18	6.6%	-0.60 [-1.27, 0.07]
Cooper 2015	0.56	0.22	24	0.71	0.13	24	7.6%	-0.82 [-1.41, -0.23]
Funabiki 2018	15.98	3.32	64	17.23	1.74	30	10.2%	-0.43 [-0.86, 0.01]
Lind 2014	0.67	0.24	20	0.75	0.19	20	7.1%	-0.36 [-0.99, 0.26]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	5.8%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	7.7%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	5.6%	-0.36 [-1.12, 0.40]
Massand 2015	0.575	0.25	15	0.715	0.17	18	6.2%	-0.65 [-1.36, 0.05]
Renner 2000	0.59	0.09	14	0.58	0.085	14	5.8%	0.11 [-0.63, 0.85]
Ring 2018	0.72	0.18	37	0.82	0.14	31	9.3%	-0.61 [-1.09, -0.12]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	7.0%	0.24 [-0.39, 0.88]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	9.7%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	6.5%	-0.03 [-0.70, 0.64]
Subtotal (95% CI)			**349**			**284**	**100.0%**	**-0.41 [-0.63, -0.19]**
Heterogeneity: Tau² = 0.07; Chi² = 22.51, df = 13 (P = 0.05); I² = 42%								
Test for overall effect: Z = 3.69 (P = 0.0002)								
3.1.3 Visuo-Spatial								
Bowler 2014	0.26	0.34	18	0.24	0.39	18	23.4%	0.05 [-0.60, 0.71]
Cooper 2015	0.48	0.26	24	0.62	0.019	24	24.8%	-0.75 [-1.33, -0.16]
Ring 2015	0.21	0.11	25	0.17	0.11	23	25.1%	0.36 [-0.21, 0.93]
Trontel 2015	9.1	2.5	38	11.3	2.7	31	26.6%	-0.84 [-1.34, -0.34]
Subtotal (95% CI)			**105**			**96**	**100.0%**	**-0.31 [-0.90, 0.29]**
Heterogeneity: Tau² = 0.28; Chi² = 12.86, df = 3 (P = 0.005); I² = 77%								
Test for overall effect: Z = 1.01 (P = 0.31)								



Test for subgroup differences: Chi² = 2.02, df = 2 (P = 0.36), I² = 1.1%

Supplementary Table 12 - Forest plot of subgroup comparison on LTM performance according to type of retrieval between ASD people and TD controls

Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.1.1 Recognition								
Blair 2002	29.47	3.29333333	12	28.22166667	3.39666667	12	4.6%	0.36 [-0.45, 1.17]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	5.5%	0.24 [-0.47, 0.95]
Bowler 2008	0.52325	0.0355	20	0.5265	0.03475	20	6.5%	-0.09 [-0.71, 0.53]
Bowler 2014	0.515	0.285	18	0.565	0.27	18	6.1%	-0.18 [-0.83, 0.48]
Cooper 2015	0.52	0.24	24	0.665	0.0745	24	6.9%	-0.80 [-1.39, -0.21]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	4.4%	-0.85 [-1.67, -0.02]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	6.0%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	6.6%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	6.0%	0.06 [-0.60, 0.72]
Lind 2014	0.67	0.24	20	0.75	0.19	20	6.5%	-0.36 [-0.99, 0.26]
Massand 2013	0.68	0.16	22	0.64	0.17	14	5.9%	0.24 [-0.43, 0.91]
Massand 2015	0.575	0.25	15	0.715	0.17	18	5.5%	-0.65 [-1.36, 0.05]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	5.4%	-0.75 [-1.47, -0.03]
Phelan 2011	13.6	1.45	15	12.6	4.27	15	5.4%	0.31 [-0.42, 1.03]
Renner 2000	0.95	0.07	14	0.94	0.07	14	5.2%	0.14 [-0.60, 0.88]
Ring 2015	0.21	0.11	25	0.17	0.11	23	7.2%	0.36 [-0.21, 0.93]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	6.3%	0.24 [-0.39, 0.88]
Subtotal (95% CI)			**307**			**295**	**100.0%**	**-0.15 [-0.35, 0.06]**
Heterogeneity: Tau² = 0.06; Chi² = 24.52, df = 16 (P = 0.08); I² = 35%								
Test for overall effect: Z = 1.41 (P = 0.16)								
5.1.2 Cued recall								
Bowler 2010	0.44	0.0525	16	0.4375	0.04	16	16.0%	0.05 [-0.64, 0.75]
Grainger 2014	0.18	0.15	18	0.31	0.22	18	16.9%	-0.68 [-1.35, -0.00]
Phelan 2011	11.2	2.66	15	10.65	3.71	15	14.9%	0.17 [-0.55, 0.88]
Williams 2005	10.48	2.62	29	10.455	2.81	34	31.3%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	21.0%	0.00 [-0.60, 0.60]
Subtotal (95% CI)			**99**			**104**	**100.0%**	**-0.08 [-0.36, 0.20]**
Heterogeneity: Tau² = 0.00; Chi² = 3.78, df = 4 (P = 0.44); I² = 0%								
Test for overall effect: Z = 0.55 (P = 0.58)								
5.1.3 Free recall								
Bowler 1997	5.595	2.08	16	6.81	1.215	16	4.3%	-0.70 [-1.41, 0.02]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	5.6%	0.00 [-0.62, 0.62]
Funabiki 2018	12.30333333	2.20666667	64	12.99666667	1.44	30	10.4%	-0.34 [-0.78, 0.09]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	5.6%	-0.23 [-0.85, 0.39]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	4.1%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	6.2%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	3.8%	-0.36 [-1.12, 0.40]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	5.4%	0.09 [-0.54, 0.73]
Phelan 2011	10.1	3.635	15	10.215	3.77	15	4.3%	-0.03 [-0.75, 0.69]
Powell 2017	36.8	9.5	29	42.7	11.2	30	7.7%	-0.56 [-1.08, -0.04]
Renner 2000	0.23	0.11	14	0.22	0.1	14	4.1%	0.09 [-0.65, 0.83]
Ring 2018	0.72	0.18	37	0.82	0.14	31	8.6%	-0.61 [-1.09, -0.12]
Smith 2007	2.17	1.17	12	2.33	1.065	12	3.5%	-0.14 [-0.94, 0.66]
Trontel 2015	9.1	2.5	38	11.3	2.7	31	8.4%	-0.84 [-1.34, -0.34]
Williams 2012	13.69	3.46	17	13.79	2.78	17	4.9%	-0.03 [-0.70, 0.64]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	4.2%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	8.9%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**400**			**362**	**100.0%**	**-0.38 [-0.53, -0.22]**
Heterogeneity: Tau² = 0.01; Chi² = 17.68, df = 16 (P = 0.34); I² = 9%								
Test for overall effect: Z = 4.80 (P < 0.00001)								

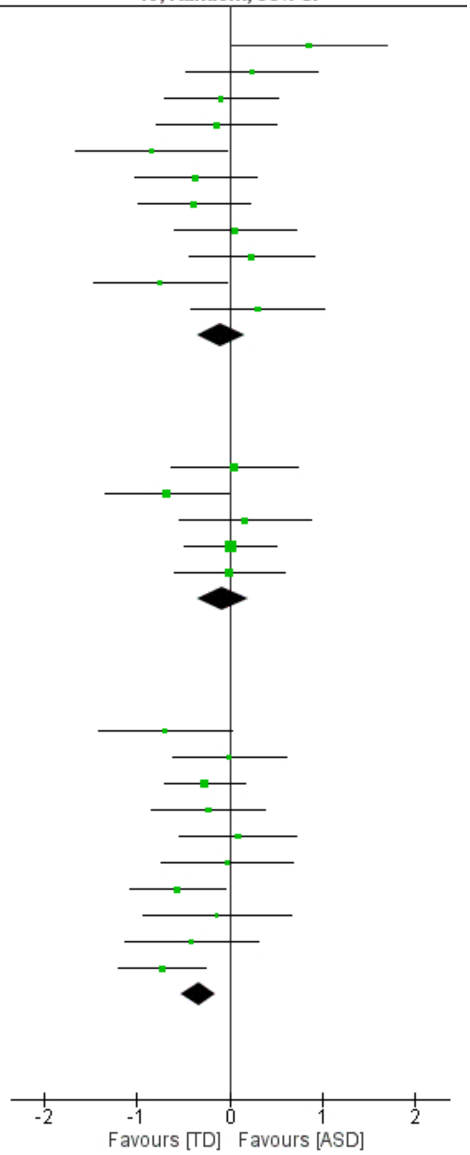


Test for subgroup differences: Chi² = 5.15, df = 2 (P = 0.08), I² = 61.2%

Supplementary Table 13 - Forest plot of subgroup comparison on verbal LTM performance according to type of retrieval between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
7.1.1 Recognition								
Blair 2002	48	2.8	12	44.25	5.26	12	7.0%	0.86 [0.02, 1.70]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	8.9%	0.24 [-0.47, 0.95]
Bowler 2008	0.52325	0.0355	20	0.5265	0.03475	20	10.4%	-0.09 [-0.71, 0.53]
Bowler 2015	0.65	0.23	18	0.68	0.19	18	9.8%	-0.14 [-0.79, 0.52]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	7.2%	-0.85 [-1.67, -0.02]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	9.7%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	10.6%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	9.6%	0.06 [-0.60, 0.72]
Massand 2013	0.68	0.16	22	0.64	0.17	14	9.5%	0.24 [-0.43, 0.91]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	8.7%	-0.75 [-1.47, -0.03]
Phelan 2011	13.6	1.45	15	12.6	4.27	15	8.7%	0.31 [-0.42, 1.03]
Subtotal (95% CI)			**190**			**177**	**100.0%**	**-0.09 [-0.35, 0.18]**
Heterogeneity: Tau² = 0.08; Chi² = 16.05, df = 10 (P = 0.10); I² = 38%								
Test for overall effect: Z = 0.66 (P = 0.51)								
7.1.2 Cued recall								
Bowler 2010	0.44	0.0525	16	0.4375	0.04	16	16.0%	0.05 [-0.64, 0.75]
Grainger 2014	0.18	0.15	18	0.31	0.22	18	16.9%	-0.68 [-1.35, -0.00]
Phelan 2011	11.2	2.66	15	10.65	3.71	15	14.9%	0.17 [-0.55, 0.88]
Williams 2005	10.48	2.62	29	10.455	2.81	34	31.3%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	21.0%	0.00 [-0.60, 0.60]
Subtotal (95% CI)			**99**			**104**	**100.0%**	**-0.08 [-0.36, 0.20]**
Heterogeneity: Tau² = 0.00; Chi² = 3.78, df = 4 (P = 0.44); I² = 0%								
Test for overall effect: Z = 0.55 (P = 0.58)								
7.1.3 Free recall								
Bowler 1997	5.595	2.08	16	6.81	1.215	16	6.9%	-0.70 [-1.41, 0.02]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	9.2%	0.00 [-0.62, 0.62]
Funabiki 2018	10.465	1.65	64	10.88	1.29	30	18.6%	-0.27 [-0.70, 0.17]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	9.1%	-0.23 [-0.85, 0.39]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	8.7%	0.09 [-0.54, 0.73]
Phelan 2011	10.1	3.635	15	10.215	3.77	15	6.9%	-0.03 [-0.75, 0.69]
Powell 2017	36.8	9.5	29	42.7	11.2	30	13.0%	-0.56 [-1.08, -0.04]
Smith 2007	2.17	1.17	12	2.33	1.065	12	5.5%	-0.14 [-0.94, 0.66]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	6.7%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	15.4%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**241**			**219**	**100.0%**	**-0.33 [-0.52, -0.14]**
Heterogeneity: Tau² = 0.00; Chi² = 8.32, df = 9 (P = 0.50); I² = 0%								
Test for overall effect: Z = 3.47 (P = 0.0005)								

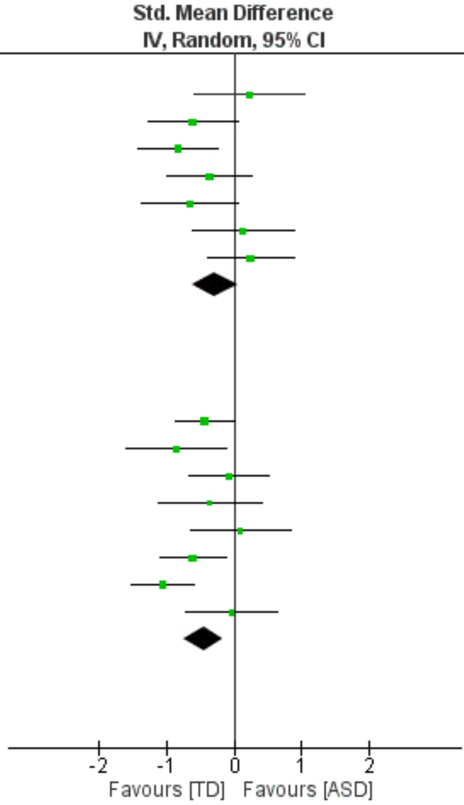
Std. Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 3.30, df = 2 (P = 0.19), I² = 39.4%

Supplementary Table 14 - Forest plot of subgroup comparison on visual LTM performance according to type of retrieval between ASD people and TD controls

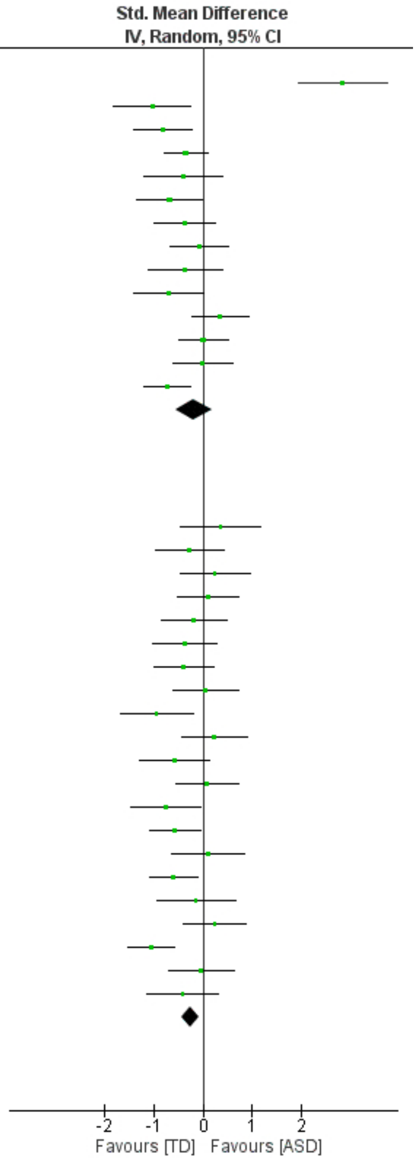
	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
7.2.1 Recognition								
Blair 2002	25.764	3.392	12	25.016	3.024	12	11.6%	0.22 [-0.58, 1.03]
Bowler 2014	0.77	0.23	18	0.89	0.15	18	14.5%	-0.60 [-1.27, 0.07]
Cooper 2015	0.56	0.22	24	0.71	0.13	24	16.6%	-0.82 [-1.41, -0.23]
Lind 2014	0.67	0.24	20	0.75	0.19	20	15.6%	-0.36 [-0.99, 0.26]
Massand 2015	0.575	0.25	15	0.715	0.17	18	13.6%	-0.65 [-1.36, 0.05]
Renner 2000	0.95	0.07	14	0.94	0.07	14	12.8%	0.14 [-0.60, 0.88]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	15.3%	0.24 [-0.39, 0.88]
Subtotal (95% CI)			**122**			**125**	**100.0%**	**-0.29 [-0.62, 0.05]**
Heterogeneity: Tau² = 0.09; Chi² = 10.49, df = 6 (P = 0.11); I² = 43%								
Test for overall effect: Z = 1.66 (P = 0.10)								
7.2.2 Free recall								
Funabiki 2018	15.98	3.32	64	17.23	1.74	30	16.8%	-0.43 [-0.86, 0.01]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	9.6%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	12.7%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	9.3%	-0.36 [-1.12, 0.40]
Renner 2000	0.23	0.11	14	0.22	0.1	14	9.6%	0.09 [-0.65, 0.83]
Ring 2018	0.72	0.18	37	0.82	0.14	31	15.3%	-0.61 [-1.09, -0.12]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	15.9%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	10.9%	-0.03 [-0.70, 0.64]
Subtotal (95% CI)			**241**			**173**	**100.0%**	**-0.45 [-0.73, -0.17]**
Heterogeneity: Tau² = 0.07; Chi² = 12.95, df = 7 (P = 0.07); I² = 46%								
Test for overall effect: Z = 3.11 (P = 0.002)								



Test for subgroup differences: Chi² = 0.52, df = 1 (P = 0.47), I² = 0%

Supplementary Table 15 - Forest plot of subgroup comparison on associative and non-associative LTM performance between ASD people and TD controls.

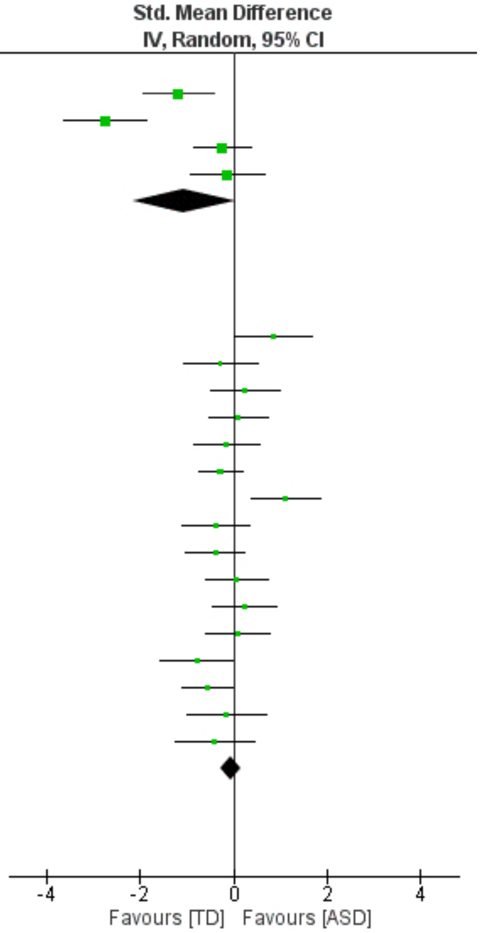
	ASD			TD				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
9.1.1 Associative memory								
Bowler 2008	0.105	0.029	20	0.04	0.013	20	5.9%	2.83 [1.93, 3.74]
Bowler 2014	0.31	0.24	14	0.58	0.27	15	6.5%	-1.03 [-1.81, -0.24]
Cooper 2015	0.52	0.24	24	0.665	0.0745	24	7.4%	-0.80 [-1.39, -0.21]
Funabiki 2018	12.30333333	2.20666667	64	12.99666667	1.44	30	8.1%	-0.34 [-0.78, 0.09]
Gaigg 2015	0.95	0.06	13	0.97	0.03	12	6.4%	-0.40 [-1.20, 0.39]
Grainger 2014	0.18	0.15	18	0.31	0.22	18	7.0%	-0.68 [-1.35, -0.00]
Lind 2014	0.67	0.24	20	0.75	0.19	20	7.2%	-0.36 [-0.99, 0.26]
Loth 2011A	32.2	12.2	25	33	10.1	20	7.4%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	6.6%	-0.36 [-1.12, 0.40]
Massand 2015	0.36	0.34	15	0.56	0.23	18	6.8%	-0.68 [-1.39, 0.02]
Ring 2015	0.21	0.11	25	0.17	0.11	23	7.5%	0.36 [-0.21, 0.93]
Williams 2005	10.48	2.62	29	10.455	2.81	34	7.8%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	7.3%	0.00 [-0.60, 0.60]
Young 2019	6.7	2.5	32	8.8	3.1	41	7.9%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**333**			**310**	**100.0%**	**-0.19 [-0.56, 0.18]**
Heterogeneity: Tau² = 0.39; Chi² = 65.92, df = 13 (P < 0.00001); I² = 80%								
Test for overall effect: Z = 1.01 (P = 0.31)								
9.1.2 No associative memory								
Blair 2002	29.47	3.29333333	12	28.22166667	3.39666667	12	3.6%	0.36 [-0.45, 1.17]
Bowler 1997	5.06	2.18	16	5.56	1.37	16	4.4%	-0.27 [-0.96, 0.43]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	4.3%	0.24 [-0.47, 0.95]
Bowler 2008	0.32	0.053	20	0.315	0.041	20	5.1%	0.10 [-0.52, 0.72]
Bowler 2014	0.515	0.285	18	0.565	0.27	18	4.8%	-0.18 [-0.83, 0.48]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	4.7%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	5.2%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	4.7%	0.06 [-0.60, 0.72]
Lopez 2008	7.67	2.16	15	9.62	1.89	16	4.0%	-0.94 [-1.69, -0.19]
Massand 2013	0.68	0.16	22	0.64	0.17	14	4.6%	0.24 [-0.43, 0.91]
Massand 2015	0.79	0.16	15	0.87	0.11	18	4.4%	-0.58 [-1.28, 0.12]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	4.9%	0.09 [-0.54, 0.73]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	4.2%	-0.75 [-1.47, -0.03]
Powell 2017	36.8	9.5	29	42.7	11.2	30	6.1%	-0.56 [-1.08, -0.04]
Renner 2000	0.59	0.09	14	0.58	0.085	14	4.1%	0.11 [-0.63, 0.85]
Ring 2018	0.72	0.18	37	0.82	0.14	31	6.5%	-0.61 [-1.09, -0.12]
Smith 2007	2.09	1.12	12	2.25	1.01	12	3.7%	-0.14 [-0.95, 0.66]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	4.9%	0.24 [-0.39, 0.88]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	6.8%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	4.6%	-0.03 [-0.70, 0.64]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	4.2%	-0.41 [-1.13, 0.32]
Subtotal (95% CI)			**425**			**389**	**100.0%**	**-0.26 [-0.44, -0.07]**
Heterogeneity: Tau² = 0.08; Chi² = 33.81, df = 20 (P = 0.03); I² = 41%								
Test for overall effect: Z = 2.73 (P = 0.006)								



Test for subgroup differences: Chi² = 0.10, df = 1 (P = 0.75), I² = 0%

Supplementary Table 16 - Forest plot of subgroup comparison on LTM performance related semantic or non-related links between ASD people and TD controls.

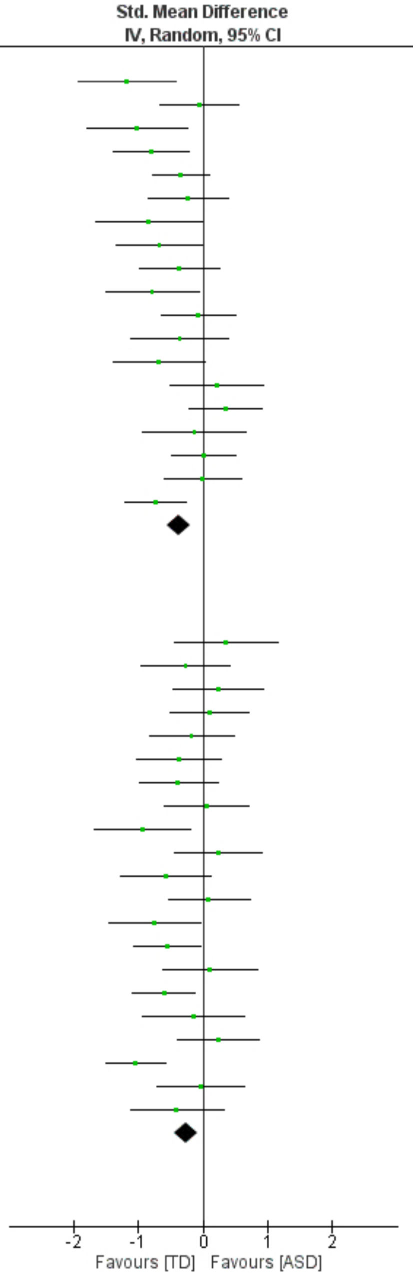
Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
11.1.1 Semantic link								
Bowler 1997	6.13	1.98	16	8.06	1.06	16	25.1%	-1.18 [-1.94, -0.43]
Bowler 2008	0.335	0.037	20	0.435	0.034	20	24.0%	-2.76 [-3.65, -1.87]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	26.1%	-0.23 [-0.85, 0.39]
Smith 2007	2.25	1.22	12	2.41	1.12	12	24.8%	-0.13 [-0.93, 0.67]
Subtotal (95% CI)			**68**			**68**	**100.0%**	**-1.05 [-2.16, 0.05]**
Heterogeneity: Tau² = 1.11; Chi² = 25.32, df = 3 (P < 0.0001); I² = 88%								
Test for overall effect: Z = 1.87 (P = 0.06)								
11.1.2 No semantic link								
Blair 2002	48	2.8	12	44.25	5.26	12	5.0%	0.86 [0.02, 1.70]
Bowler 1997	5.06	2.18	10	5.56	1.37	16	5.4%	-0.28 [-1.08, 0.51]
Bowler 2000	0.58	0.22	13	0.53	0.18	15	5.8%	0.24 [-0.50, 0.99]
Bowler 2008	0.32	0.053	17	0.315	0.041	20	6.9%	0.10 [-0.54, 0.75]
Bowler 2015	0.65	0.23	13	0.68	0.19	18	6.1%	-0.14 [-0.86, 0.57]
Funabiki 2018	10.465	1.65	38	10.88	1.29	30	9.1%	-0.27 [-0.75, 0.21]
Gaigg 2008	0.17	0.04	15	0.135	0.02	18	5.9%	1.11 [0.37, 1.86]
Grainger 2014	0.65	0.23	13	0.73	0.19	18	6.1%	-0.38 [-1.10, 0.34]
Grainger 2016	1.75	0.73	19	2.02	0.65	20	7.0%	-0.38 [-1.02, 0.25]
Komeda 2013	0.7245	0.188	17	0.7132	0.1818	17	6.6%	0.06 [-0.61, 0.73]
Massand 2013	0.68	0.16	20	0.64	0.17	14	6.4%	0.24 [-0.45, 0.92]
Mayer 2014	81.72	15.77	15	80.38	12.26	19	6.5%	0.09 [-0.58, 0.77]
Meyer 2014	0.6	0.27	12	0.77	0.155	16	5.5%	-0.78 [-1.56, -0.00]
Powell 2017	36.8	9.5	24	42.7	11.2	30	8.1%	-0.55 [-1.10, -0.01]
Smith 2007	2.09	1.12	9	2.25	1.01	12	4.8%	-0.15 [-1.01, 0.72]
Yamamoto 2018	0.58	0.22	8	0.67	0.21	16	4.9%	-0.41 [-1.27, 0.45]
Subtotal (95% CI)			**255**			**291**	**100.0%**	**-0.06 [-0.29, 0.17]**
Heterogeneity: Tau² = 0.09; Chi² = 25.94, df = 15 (P = 0.04); I² = 42%								
Test for overall effect: Z = 0.50 (P = 0.62)								



Test for subgroup differences: Chi² = 2.99, df = 1 (P = 0.08), I² = 66.6%

Supplementary Table 17 - Forest plot of subgroup comparison on whole associative and no organisation LTM performance between ASD people and TD controls.

Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
15.1.1 Associative memory and/or semantic link								
Bowler 1997	6.13	1.98	16	8.06	1.06	16	4.2%	-1.18 [-1.94, -0.43]
Bowler 2008	0.19333333	0.03566667	20	0.195	0.025	20	5.5%	-0.05 [-0.67, 0.57]
Bowler 2014	0.31	0.24	14	0.58	0.27	15	4.1%	-1.03 [-1.81, -0.24]
Cooper 2015	0.52	0.24	24	0.665	0.0745	24	5.8%	-0.80 [-1.39, -0.21]
Funabiki 2018	12.30333333	2.20666667	64	12.99666667	1.44	30	7.8%	-0.34 [-0.78, 0.09]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	5.4%	-0.23 [-0.85, 0.39]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	3.8%	-0.85 [-1.67, -0.02]
Grainger 2014	0.18	0.15	18	0.31	0.22	18	4.9%	-0.68 [-1.35, -0.00]
Lind 2014	0.67	0.24	20	0.75	0.19	20	5.4%	-0.36 [-0.99, 0.26]
Lopez 2008	11.8	4.1	15	14.37	1.99	16	4.4%	-0.79 [-1.52, -0.05]
Loth 2011A	32.2	12.2	25	33	10.1	20	5.8%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	4.2%	-0.36 [-1.12, 0.40]
Massand 2015	0.36	0.34	15	0.56	0.23	18	4.6%	-0.68 [-1.39, 0.02]
Phelan 2011	12	2.25666667	15	11.3	3.89666667	15	4.5%	0.21 [-0.50, 0.93]
Ring 2015	0.21	0.11	25	0.17	0.11	23	6.0%	0.36 [-0.21, 0.93]
Smith 2007	2.25	1.22	12	2.41	1.12	12	3.9%	-0.13 [-0.93, 0.67]
Williams 2005	10.48	2.62	29	10.455	2.81	34	6.9%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	5.6%	0.00 [-0.60, 0.60]
Young 2019	6.7	2.5	32	8.8	3.1	41	7.2%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**411**			**389**	**100.0%**	**-0.38 [-0.56, -0.19]**
Heterogeneity: Tau² = 0.07; Chi² = 30.40, df = 18 (P = 0.03); I² = 41%								
Test for overall effect: Z = 3.90 (P < 0.0001)								
15.1.2 No organization memory								
Blair 2002	29.47	3.29333333	12	28.22166667	3.39666667	12	3.6%	0.36 [-0.45, 1.17]
Bowler 1997	5.06	2.18	16	5.56	1.37	16	4.4%	-0.27 [-0.96, 0.43]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	4.3%	0.24 [-0.47, 0.95]
Bowler 2008	0.32	0.053	20	0.315	0.041	20	5.1%	0.10 [-0.52, 0.72]
Bowler 2014	0.515	0.285	18	0.565	0.27	18	4.8%	-0.18 [-0.83, 0.48]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	4.7%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	5.2%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	4.7%	0.06 [-0.60, 0.72]
Lopez 2008	7.67	2.16	15	9.62	1.89	16	4.0%	-0.94 [-1.69, -0.19]
Massand 2013	0.68	0.16	22	0.64	0.17	14	4.6%	0.24 [-0.43, 0.91]
Massand 2015	0.79	0.16	15	0.87	0.11	18	4.4%	-0.58 [-1.28, 0.12]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	4.9%	0.09 [-0.54, 0.73]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	4.2%	-0.75 [-1.47, -0.03]
Powell 2017	36.8	9.5	29	42.7	11.2	30	6.1%	-0.56 [-1.08, -0.04]
Renner 2000	0.59	0.09	14	0.58	0.085	14	4.1%	0.11 [-0.63, 0.85]
Ring 2018	0.72	0.18	37	0.82	0.14	31	6.5%	-0.61 [-1.09, -0.12]
Smith 2007	2.09	1.12	12	2.25	1.01	12	3.7%	-0.14 [-0.95, 0.66]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	4.9%	0.24 [-0.39, 0.88]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	6.8%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	4.6%	-0.03 [-0.70, 0.64]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	4.2%	-0.41 [-1.13, 0.32]
Subtotal (95% CI)			**425**			**389**	**100.0%**	**-0.26 [-0.44, -0.07]**
Heterogeneity: Tau² = 0.08; Chi² = 33.81, df = 20 (P = 0.03); I² = 41%								
Test for overall effect: Z = 2.73 (P = 0.006)								

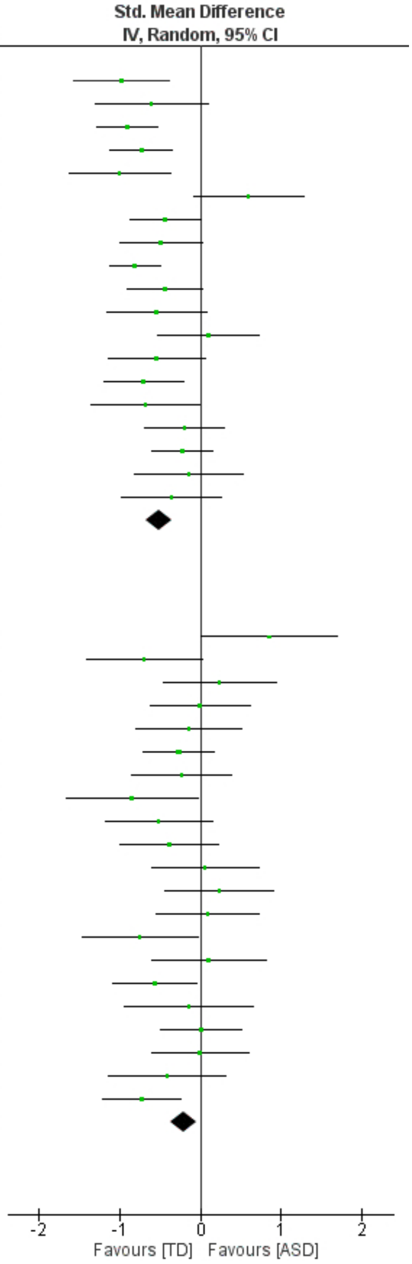


Test for subgroup differences: Chi² = 0.77, df = 1 (P = 0.38), I² = 0%

Supplementary Table 18 - Forest plot of subgroup comparison on verbal performance depending on LTM or STM between ASD people and TD controls

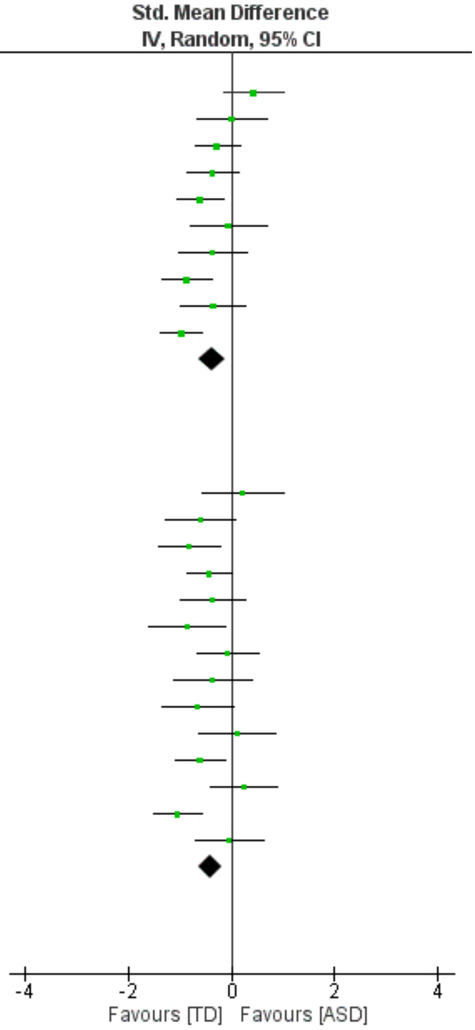
	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
12.1.1 STM								
Alloway 2016	59.16166667	13.23333333	26	71.7	11.88833333	23	4.5%	-0.98 [-1.57, -0.38]
Braden 2017	89.45	10.4	16	94.75	6.2	17	3.7%	-0.61 [-1.31, 0.09]
Chen 2016A	6.035	1.39	53	7.255	1.29	63	7.2%	-0.91 [-1.29, -0.52]
Chen 2016B	6.905	1.355	58	7.795	1.015	51	7.1%	-0.73 [-1.12, -0.34]
Christ 2017	13.6	2.4	22	16.1	2.5	22	4.2%	-1.00 [-1.63, -0.37]
Cui 2010	7.21875	1.77125	12	6.3375	1.28875	29	3.8%	0.60 [-0.09, 1.29]
Funabiki 2018	8.7725	1.89	64	9.585	1.745	30	6.4%	-0.44 [-0.87, 0.00]
Garcia-Molina 2019	9.69	3.64	30	11.33	2.93	30	5.4%	-0.49 [-1.00, 0.02]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	8.3%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	5.9%	-0.44 [-0.91, 0.04]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.3%	-0.54 [-1.16, 0.08]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	4.2%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.5%	-0.55 [-1.15, 0.06]
Trontel 2015	7.9	3.025	38	9.975	2.775	31	5.7%	-0.70 [-1.19, -0.21]
Vogan 2014	101.53	18.03	19	113.98	17.98333333	17	3.9%	-0.68 [-1.35, -0.00]
Williams 2005	10.86	3.07	29	11.38	2.24	34	5.6%	-0.19 [-0.69, 0.30]
Williams 2006	10.05	3.09	56	10.73	2.84	56	7.3%	-0.23 [-0.60, 0.14]
Williams 2014	6.705	1.115	17	6.84	0.735	17	3.9%	-0.14 [-0.81, 0.53]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.3%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**632**			**634**	**100.0%**	**-0.51 [-0.67, -0.35]**
Heterogeneity: Tau² = 0.06; Chi² = 33.20, df = 18 (P = 0.02); I² = 46%								
Test for overall effect: Z = 6.21 (P < 0.00001)								
12.1.2 LTM								
Blair 2002	48	2.8	12	44.25	5.26	12	3.1%	0.86 [0.02, 1.70]
Bowler 1997	5.595	2.08	16	6.81	1.215	16	4.0%	-0.70 [-1.41, 0.02]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	4.1%	0.24 [-0.47, 0.95]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	5.0%	0.00 [-0.62, 0.62]
Bowler 2015	0.65	0.23	18	0.68	0.19	18	4.6%	-0.14 [-0.79, 0.52]
Funabiki 2018	10.465	1.65	64	10.88	1.29	30	7.8%	-0.27 [-0.70, 0.17]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	4.9%	-0.23 [-0.85, 0.39]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	3.2%	-0.85 [-1.67, -0.02]
Grainger 2014	0.415	0.19	18	0.52	0.205	18	4.5%	-0.52 [-1.19, 0.15]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	5.0%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	4.5%	0.06 [-0.60, 0.72]
Massand 2013	0.68	0.16	22	0.64	0.17	14	4.4%	0.24 [-0.43, 0.91]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	4.8%	0.09 [-0.54, 0.73]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	3.9%	-0.75 [-1.47, -0.03]
Phelan 2011	11.24	2.808	15	10.866	3.846	15	4.0%	0.11 [-0.61, 0.82]
Powell 2017	36.8	9.5	29	42.7	11.2	30	6.3%	-0.56 [-1.08, -0.04]
Smith 2007	2.17	1.17	12	2.33	1.065	12	3.3%	-0.14 [-0.94, 0.66]
Williams 2005	10.48	2.62	29	10.455	2.81	34	6.7%	0.01 [-0.49, 0.50]
Wojcik 2014	0.34	0.25	21	0.34	0.235	21	5.1%	0.00 [-0.60, 0.60]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	3.9%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	7.0%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**446**			**416**	**100.0%**	**-0.21 [-0.38, -0.05]**
Heterogeneity: Tau² = 0.04; Chi² = 27.37, df = 20 (P = 0.13); I² = 27%								
Test for overall effect: Z = 2.58 (P = 0.010)								

Test for subgroup differences: Chi² = 6.42, df = 1 (P = 0.01), I² = 84.4%



Supplementary Table 19 - Forest plot of subgroup comparison on visual performance depending on LTM or STM between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
12.2.1 STM								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	9.5%	0.43 [-0.15, 1.01]
Cui 2010	4.0225	1.7125	12	4.0075	0.88	29	8.2%	0.01 [-0.66, 0.69]
Funabiki 2018	37.45	3.15	64	38.23	2.16	30	11.9%	-0.27 [-0.70, 0.17]
Garcia-Molina 2019	9.59	3.26	30	10.57	1.94	30	10.6%	-0.36 [-0.87, 0.15]
Geurts 2004	5	1.7	41	6.1	1.9	41	11.7%	-0.60 [-1.05, -0.16]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	7.4%	-0.06 [-0.80, 0.69]
Ring 2016	0.525	0.245	18	0.61	0.225	18	8.4%	-0.35 [-1.01, 0.31]
Trontel 2015	8.45	3.25	38	11.05	2.7	31	10.8%	-0.85 [-1.35, -0.36]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	8.9%	-0.35 [-0.98, 0.27]
Verté 2005	5	1.9	61	6.7	1.5	47	12.5%	-0.97 [-1.37, -0.57]
Subtotal (95% CI)			**313**			**298**	**100.0%**	**-0.38 [-0.64, -0.11]**
Heterogeneity: Tau² = 0.11; Chi² = 22.05, df = 9 (P = 0.009); I² = 59%								
Test for overall effect: Z = 2.78 (P = 0.005)								
12.2.2 LTM								
Blair 2002	25.764	3.392	12	25.016	3.024	12	5.2%	0.22 [-0.58, 1.03]
Bowler 2014	0.77	0.23	18	0.89	0.15	18	6.6%	-0.60 [-1.27, 0.07]
Cooper 2015	0.56	0.22	24	0.71	0.13	24	7.6%	-0.82 [-1.41, -0.23]
Funabiki 2018	15.98	3.32	64	17.23	1.74	30	10.2%	-0.43 [-0.86, 0.01]
Lind 2014	0.67	0.24	20	0.75	0.19	20	7.1%	-0.36 [-0.99, 0.26]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	5.8%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	7.7%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	5.6%	-0.36 [-1.12, 0.40]
Massand 2015	0.575	0.25	15	0.715	0.17	18	6.2%	-0.65 [-1.36, 0.05]
Renner 2000	0.59	0.09	14	0.58	0.085	14	5.8%	0.11 [-0.63, 0.85]
Ring 2018	0.72	0.18	37	0.82	0.14	31	9.3%	-0.61 [-1.09, -0.12]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	7.0%	0.24 [-0.39, 0.88]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	9.7%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	6.5%	-0.03 [-0.70, 0.64]
Subtotal (95% CI)			**349**			**284**	**100.0%**	**-0.41 [-0.63, -0.19]**
Heterogeneity: Tau² = 0.07; Chi² = 22.51, df = 13 (P = 0.05); I² = 42%								
Test for overall effect: Z = 3.69 (P = 0.0002)								

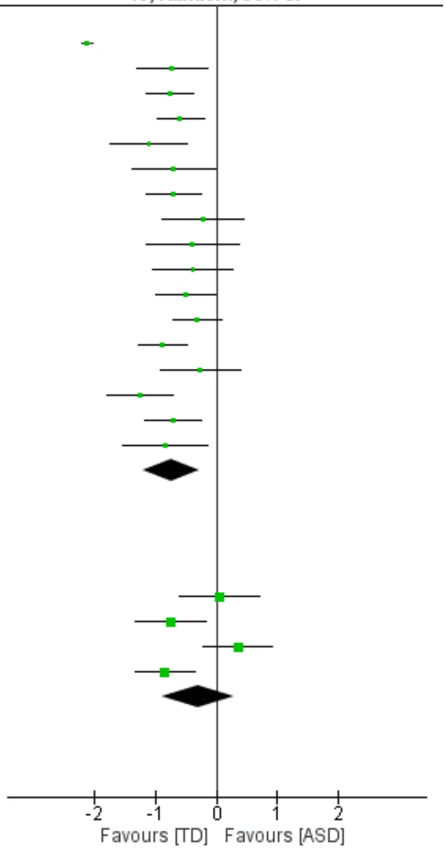


Test for subgroup differences: Chi² = 0.03, df = 1 (P = 0.85), I² = 0%

Supplementary Table 20 - Forest plot of subgroup comparison on visuo-spatial performance depending on LTM or STM between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
12.3.1 STM								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	6.4%	-2.12 [-2.21, -2.03]
Alloway 2016	85.335	16.005	26	97.4	16.9025	23	5.8%	-0.72 [-1.30, -0.14]
Chen 2016A	6.04	1.68	53	7.14	1.19	63	6.1%	-0.76 [-1.14, -0.38]
Chen 2016B	7.16	1.5	58	7.98	1.24	51	6.1%	-0.59 [-0.97, -0.20]
Christ 2017	12.8	3.3	22	16.4	3.1	22	5.7%	-1.10 [-1.74, -0.47]
Cui 2010	3.535	0.6875	12	3.9525	0.545	29	5.6%	-0.70 [-1.39, -0.00]
Geurts 2004	4.4	0.9	41	5	0.8	41	6.0%	-0.70 [-1.14, -0.25]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	5.6%	-0.22 [-0.90, 0.45]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	5.5%	-0.39 [-1.14, 0.36]
Ring 2016	0.5	0.22	18	0.58	0.19	18	5.7%	-0.38 [-1.04, 0.28]
Trontel 2015	9.8	4.5	38	11.9	3.6	31	6.0%	-0.50 [-0.99, -0.02]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	6.1%	-0.31 [-0.71, 0.08]
Verté 2005	4.3	0.9	61	5	0.6	47	6.1%	-0.89 [-1.29, -0.49]
Vogan 2014	95.5	18.305	19	100.85	22.105	17	5.7%	-0.26 [-0.92, 0.40]
Williams 2005	8.24	3.42	29	11.79	2.14	34	5.9%	-1.25 [-1.80, -0.71]
Williams 2006	8.61	3	38	10.89	3.35	38	6.0%	-0.71 [-1.17, -0.25]
Williams 2014	5.265	1.315	17	6.23	0.885	17	5.6%	-0.84 [-1.55, -0.14]
Subtotal (95% CI)			**2050**			**2007**	**100.0%**	**-0.74 [-1.20, -0.28]**
Heterogeneity: Tau² = 0.87; Chi² = 357.04, df = 16 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 3.14 (P = 0.002)								
12.3.2 LTM								
Bowler 2014	0.26	0.34	18	0.24	0.39	18	23.4%	0.05 [-0.60, 0.71]
Cooper 2015	0.48	0.26	24	0.62	0.019	24	24.8%	-0.75 [-1.33, -0.16]
Ring 2015	0.21	0.11	25	0.17	0.11	23	25.1%	0.36 [-0.21, 0.93]
Trontel 2015	9.1	2.5	38	11.3	2.7	31	26.6%	-0.84 [-1.34, -0.34]
Subtotal (95% CI)			**105**			**96**	**100.0%**	**-0.31 [-0.90, 0.29]**
Heterogeneity: Tau² = 0.28; Chi² = 12.86, df = 3 (P = 0.005); I² = 77%								
Test for overall effect: Z = 1.01 (P = 0.31)								

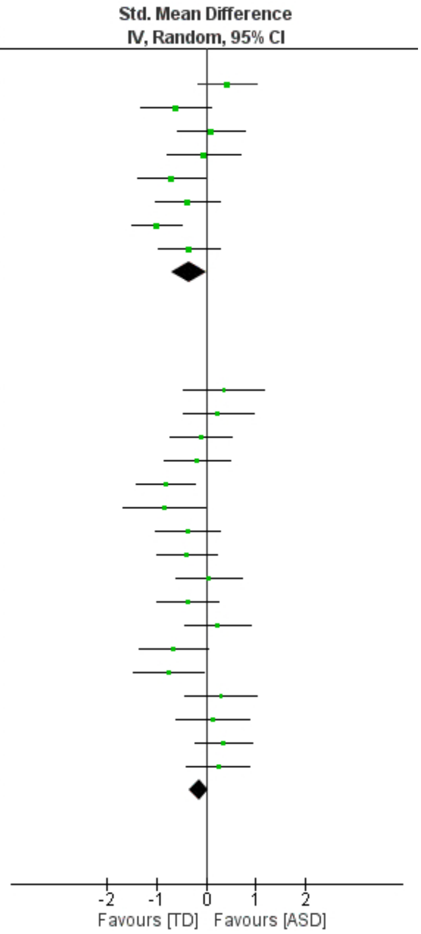
Std. Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 1.28, df = 1 (P = 0.26), I² = 22.0%

Supplementary Table 21 - Forest plot of subgroup comparison on recognition performance depending on LTM or STM between ASD people and TD controls

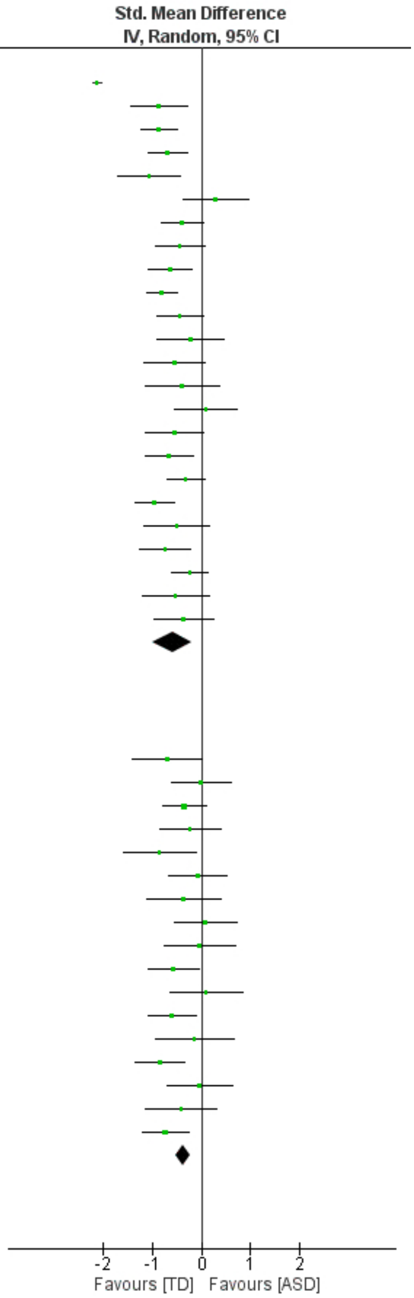
	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
13.1.1 STM								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	13.5%	0.43 [-0.15, 1.01]
Braden 2017	89.45	10.4	16	94.75	6.2	17	11.6%	-0.61 [-1.31, 0.09]
Cui 2010	0.77333333	0.11666667	12	0.76	0.13166667	29	12.0%	0.10 [-0.57, 0.78]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	11.0%	-0.06 [-0.80, 0.69]
Poirier 2011	0.68	0.21	18	0.8	0.11	18	12.0%	-0.70 [-1.38, -0.02]
Ring 2016	0.5125	0.2325	18	0.595	0.2075	18	12.2%	-0.37 [-1.03, 0.29]
Trontel 2015	9.8	3	38	12.7	2.7	31	14.9%	-1.00 [-1.50, -0.49]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	12.8%	-0.35 [-0.98, 0.27]
Subtotal (95% CI)			**151**			**185**	**100.0%**	**-0.33 [-0.68, 0.02]**
Heterogeneity: Tau² = 0.15; Chi² = 17.16, df = 7 (P = 0.02); I² = 59%								
Test for overall effect: Z = 1.82 (P = 0.07)								
13.1.2 LTM								
Blair 2002	29.47	3.29333333	12	28.22166667	3.39666667	12	4.6%	0.36 [-0.45, 1.17]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	5.5%	0.24 [-0.47, 0.95]
Bowler 2008	0.52325	0.0355	20	0.5265	0.03475	20	6.5%	-0.09 [-0.71, 0.53]
Bowler 2014	0.515	0.285	18	0.565	0.27	18	6.1%	-0.18 [-0.83, 0.48]
Cooper 2015	0.52	0.24	24	0.665	0.0745	24	6.9%	-0.80 [-1.39, -0.21]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	4.4%	-0.85 [-1.67, -0.02]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	6.0%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	6.6%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	6.0%	0.06 [-0.60, 0.72]
Lind 2014	0.67	0.24	20	0.75	0.19	20	6.5%	-0.36 [-0.99, 0.26]
Massand 2013	0.68	0.16	22	0.64	0.17	14	5.9%	0.24 [-0.43, 0.91]
Massand 2015	0.575	0.25	15	0.715	0.17	18	5.5%	-0.65 [-1.36, 0.05]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	5.4%	-0.75 [-1.47, -0.03]
Phelan 2011	13.6	1.45	15	12.6	4.27	15	5.4%	0.31 [-0.42, 1.03]
Renner 2000	0.95	0.07	14	0.94	0.07	14	5.2%	0.14 [-0.60, 0.88]
Ring 2015	0.21	0.11	25	0.17	0.11	23	7.2%	0.36 [-0.21, 0.93]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	6.3%	0.24 [-0.39, 0.88]
Subtotal (95% CI)			**307**			**295**	**100.0%**	**-0.15 [-0.35, 0.06]**
Heterogeneity: Tau² = 0.06; Chi² = 24.52, df = 16 (P = 0.08); I² = 35%								
Test for overall effect: Z = 1.41 (P = 0.16)								



Test for subgroup differences: Chi² = 0.78, df = 1 (P = 0.38), I² = 0%

Supplementary Table 22 - Forest plot of subgroup comparison on free recall performance depending on LTM or STM between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
13.2.1 STM								
Abbasy 2018	3.32	1.34	1540	5.74	0.89	1490	4.5%	-2.12 [-2.21, -2.03]
Alloway 2016	69.631	14.342	26	81.98	13.894	23	4.1%	-0.86 [-1.45, -0.27]
Chen 2016A	6.03666667	1.48666667	53	7.21666667	1.25666667	63	4.3%	-0.86 [-1.24, -0.48]
Chen 2016B	6.99	1.40333333	58	7.85666667	1.09	51	4.3%	-0.68 [-1.07, -0.29]
Christ 2017	13.2	2.85	22	16.25	2.8	22	4.0%	-1.06 [-1.70, -0.43]
Cui 2010	8.334	2.307	12	7.798	1.522	29	4.0%	0.30 [-0.38, 0.97]
Funabiki 2018	14.508	2.142	64	15.314	1.828	30	4.3%	-0.39 [-0.83, 0.05]
Garcia-Molina 2019	9.64	3.45	30	10.95	2.435	30	4.2%	-0.43 [-0.95, 0.08]
Geurts 2004	4.7	1.3	41	5.55	1.35	41	4.3%	-0.64 [-1.08, -0.19]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	4.4%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	4.2%	-0.44 [-0.91, 0.04]
Mammarella 2019	0.7	0.22333333	17	0.75	0.21666667	17	4.0%	-0.22 [-0.90, 0.45]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.1%	-0.54 [-1.16, 0.08]
Matsuura 2014	0.47	0.85	11	0.86	1.04	19	3.9%	-0.39 [-1.14, 0.36]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	4.0%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.1%	-0.55 [-1.15, 0.06]
Trontel 2015	8.08333333	3.35	38	10.2	2.9	31	4.2%	-0.66 [-1.15, -0.18]
Van Eylen 2015	7.55	1.8	50	8.06	1.39	50	4.3%	-0.31 [-0.71, 0.08]
Verté 2005	4.65	1.4	61	5.85	1.05	47	4.3%	-0.95 [-1.35, -0.54]
Vogan 2014	99.118	18.14	19	108.728	19.632	17	4.0%	-0.50 [-1.16, 0.17]
Williams 2005	9.55	3.245	29	11.585	2.19	34	4.2%	-0.74 [-1.25, -0.22]
Williams 2006	10.05	3.09	56	10.73	2.84	56	4.3%	-0.23 [-0.60, 0.14]
Williams 2014	5.985	1.215	17	6.535	0.81	17	4.0%	-0.52 [-1.21, 0.16]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.1%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**2336**			**2281**	**100.0%**	**-0.59 [-0.98, -0.19]**
Heterogeneity: Tau² = 0.91; Chi² = 541.22, df = 23 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 2.90 (P = 0.004)								
13.2.2 LTM								
Bowler 1997	5.595	2.08	16	6.81	1.215	16	4.3%	-0.70 [-1.41, 0.02]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	5.6%	0.00 [-0.62, 0.62]
Funabiki 2018	12.30333333	2.20666667	64	12.99666667	1.44	30	10.4%	-0.34 [-0.78, 0.09]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	5.6%	-0.23 [-0.85, 0.39]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	4.1%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	6.2%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	3.8%	-0.36 [-1.12, 0.40]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	5.4%	0.09 [-0.54, 0.73]
Phelan 2011	10.1	3.635	15	10.215	3.77	15	4.3%	-0.03 [-0.75, 0.69]
Powell 2017	36.8	9.5	29	42.7	11.2	30	7.7%	-0.56 [-1.08, -0.04]
Renner 2000	0.23	0.11	14	0.22	0.1	14	4.1%	0.09 [-0.65, 0.83]
Ring 2018	0.72	0.18	37	0.82	0.14	31	8.6%	-0.61 [-1.09, -0.12]
Smith 2007	2.17	1.17	12	2.33	1.065	12	3.5%	-0.14 [-0.94, 0.66]
Trontel 2015	9.1	2.5	38	11.3	2.7	31	8.4%	-0.84 [-1.34, -0.34]
Williams 2012	13.69	3.46	17	13.79	2.78	17	4.9%	-0.03 [-0.70, 0.64]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	4.2%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	8.9%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**400**			**362**	**100.0%**	**-0.38 [-0.53, -0.22]**
Heterogeneity: Tau² = 0.01; Chi² = 17.68, df = 16 (P = 0.34); I² = 9%								
Test for overall effect: Z = 4.80 (P < 0.00001)								

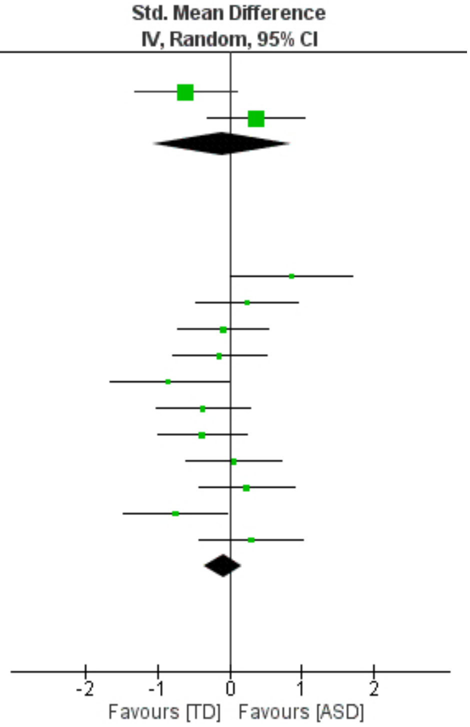


Test for subgroup differences: Chi² = 0.92, df = 1 (P = 0.34), I² = 0%

Supplementary Table 23 - Forest plot of subgroup comparison on verbal recognition performance depending on LTM or STM between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
14.1.1 STM								
Braden 2017	89.45	10.4	16	94.75	6.2	17	49.6%	-0.61 [-1.31, 0.09]
Cui 2010	0.79	0.135	12	0.74	0.13	29	50.4%	0.37 [-0.31, 1.05]
Subtotal (95% CI)			**28**			**46**	**100.0%**	**-0.11 [-1.08, 0.85]**
Heterogeneity: Tau² = 0.36; Chi² = 3.90, df = 1 (P = 0.05); I² = 74%								
Test for overall effect: Z = 0.23 (P = 0.82)								
14.1.2 LTM								
Blair 2002	48	2.8	12	44.25	5.26	12	7.0%	0.86 [0.02, 1.70]
Bowler 2000	0.58	0.22	16	0.53	0.18	15	8.9%	0.24 [-0.47, 0.95]
Bowler 2008	0.52325	0.0355	20	0.5265	0.03475	20	10.4%	-0.09 [-0.71, 0.53]
Bowler 2015	0.65	0.23	18	0.68	0.19	18	9.8%	-0.14 [-0.79, 0.52]
Gaigg 2015	0.91	0.06	13	0.955	0.04	12	7.2%	-0.85 [-1.67, -0.02]
Grainger 2014	0.65	0.23	18	0.73	0.19	18	9.7%	-0.37 [-1.03, 0.29]
Grainger 2016	1.75	0.73	22	2.02	0.65	20	10.6%	-0.38 [-0.99, 0.23]
Komeda 2013	0.7245	0.188	18	0.7132	0.1818	17	9.6%	0.06 [-0.60, 0.72]
Massand 2013	0.68	0.16	22	0.64	0.17	14	9.5%	0.24 [-0.43, 0.91]
Meyer 2014	0.6	0.27	16	0.77	0.155	16	8.7%	-0.75 [-1.47, -0.03]
Phelan 2011	13.6	1.45	15	12.6	4.27	15	8.7%	0.31 [-0.42, 1.03]
Subtotal (95% CI)			**190**			**177**	**100.0%**	**-0.09 [-0.35, 0.18]**
Heterogeneity: Tau² = 0.08; Chi² = 16.05, df = 10 (P = 0.10); I² = 38%								
Test for overall effect: Z = 0.66 (P = 0.51)								

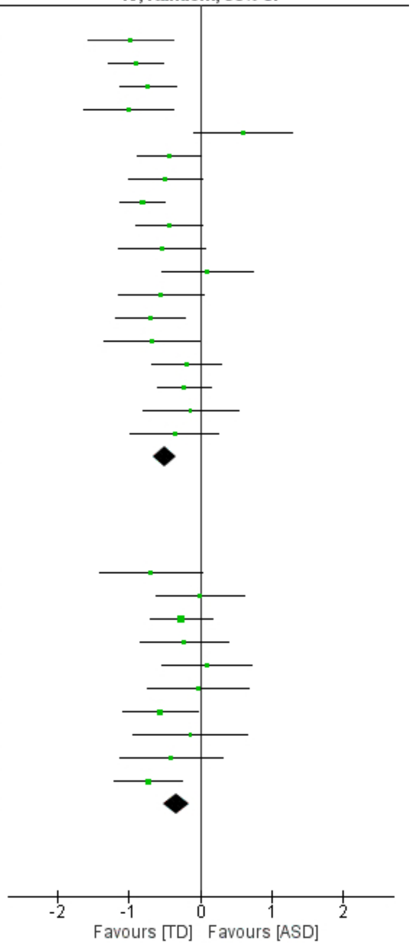
Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.96), I² = 0%



Supplementary Table 24 - Forest plot of subgroup comparison on verbal free recall performance depending on LTM or STM between ASD people and TD controls

Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
14.2.1 STM								
Alloway 2016	59.16166667	13.23333333	26	71.7	11.88833333	23	4.7%	-0.98 [-1.57, -0.38]
Chen 2016A	6.035	1.39	53	7.255	1.29	63	7.3%	-0.91 [-1.29, -0.52]
Chen 2016B	6.905	1.355	58	7.795	1.015	51	7.3%	-0.73 [-1.12, -0.34]
Christ 2017	13.6	2.4	22	16.1	2.5	22	4.4%	-1.00 [-1.63, -0.37]
Cui 2010	9.36166667	2.31666667	12	8.20333333	1.675	29	4.0%	0.60 [-0.08, 1.29]
Funabiki 2018	8.7725	1.89	64	9.585	1.745	30	6.6%	-0.44 [-0.87, 0.00]
Garcia-Molina 2019	9.69	3.64	30	11.33	2.93	30	5.6%	-0.49 [-1.00, 0.02]
Kouklari 2017	11.33	3.09	79	13.97	3.38	91	8.4%	-0.81 [-1.12, -0.50]
Li 2017	8.705	3.97	32	10.165	2.62	39	6.1%	-0.44 [-0.91, 0.04]
Martinez 2017	4.58666667	0.90666667	21	5.17333333	1.21	21	4.6%	-0.54 [-1.16, 0.08]
Mayer 2014	9.845	2.485	19	9.58	2.65	19	4.4%	0.10 [-0.54, 0.74]
Poirier 2011	0.6	0.155	22	0.685	0.15	22	4.7%	-0.55 [-1.15, 0.06]
Trontel 2015	7.9	3.025	38	9.975	2.775	31	5.9%	-0.70 [-1.19, -0.21]
Vogan 2014	101.53	18.03	19	113.98	17.98333333	17	4.1%	-0.68 [-1.35, -0.00]
Williams 2005	10.86	3.07	29	11.38	2.24	34	5.8%	-0.19 [-0.69, 0.30]
Williams 2006	10.05	3.09	56	10.73	2.84	56	7.5%	-0.23 [-0.60, 0.14]
Williams 2014	6.705	1.115	17	6.84	0.735	17	4.1%	-0.14 [-0.81, 0.53]
Yuk 2018	204	37.01	19	216.64	32.71	22	4.5%	-0.36 [-0.98, 0.26]
Subtotal (95% CI)			**616**			**617**	**100.0%**	**-0.50 [-0.67, -0.34]**
Heterogeneity: Tau² = 0.06; Chi² = 33.25, df = 17 (P = 0.01); I² = 49%								
Test for overall effect: Z = 5.89 (P < 0.00001)								
14.2.2 LTM								
Bowler 1997	5.595	2.08	16	6.81	1.215	16	6.9%	-0.70 [-1.41, 0.02]
Bowler 2008	0.225	0.04	20	0.225	0.029	20	9.2%	0.00 [-0.62, 0.62]
Funabiki 2018	10.465	1.65	64	10.88	1.29	30	18.6%	-0.27 [-0.70, 0.17]
Gaigg 2008	0.39	0.47	20	0.52	0.625	20	9.1%	-0.23 [-0.85, 0.39]
Mayer 2014	81.72	15.77	19	80.38	12.26	19	8.7%	0.09 [-0.54, 0.73]
Phelan 2011	10.1	3.635	15	10.215	3.77	15	6.9%	-0.03 [-0.75, 0.69]
Powell 2017	36.8	9.5	29	42.7	11.2	30	13.0%	-0.56 [-1.08, -0.04]
Smith 2007	2.17	1.17	12	2.33	1.065	12	5.5%	-0.14 [-0.94, 0.66]
Yamamoto 2018	0.58	0.22	14	0.67	0.21	16	6.7%	-0.41 [-1.13, 0.32]
Young 2019	6.7	2.5	32	8.8	3.1	41	15.4%	-0.73 [-1.21, -0.25]
Subtotal (95% CI)			**241**			**219**	**100.0%**	**-0.33 [-0.52, -0.14]**
Heterogeneity: Tau² = 0.00; Chi² = 8.32, df = 9 (P = 0.50); I² = 0%								
Test for overall effect: Z = 3.47 (P = 0.0005)								

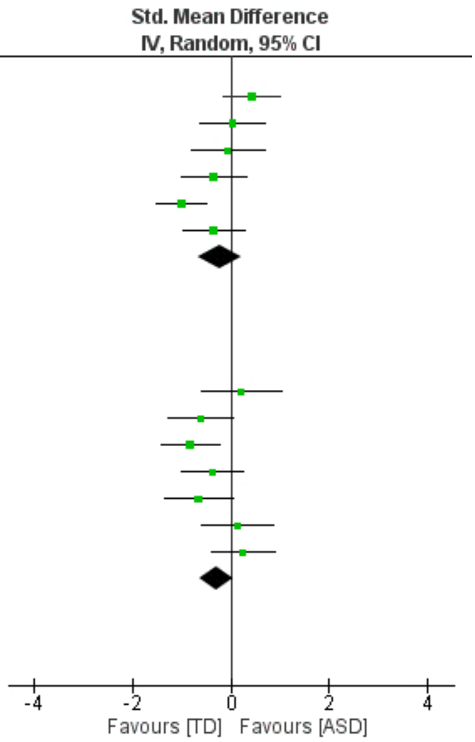
Std. Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 1.76, df = 1 (P = 0.18), I² = 43.1%

Supplementary Table 25 - Forest plot of subgroup comparison on visual recognition performance depending on LTM or STM between ASD people and TD controls

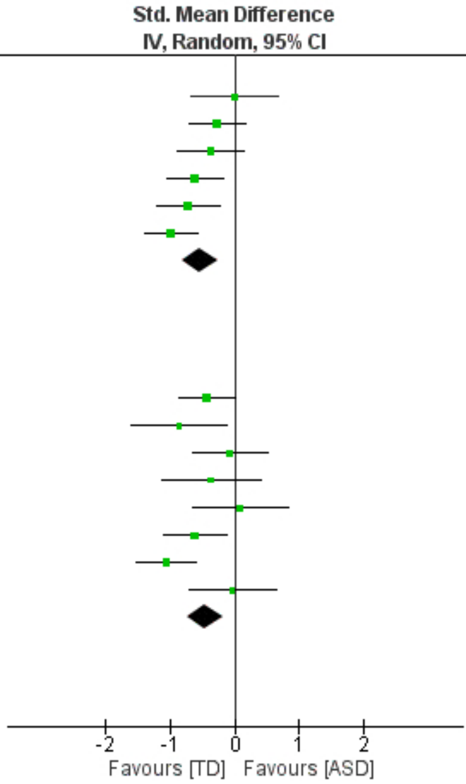
Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
14.3.1 STM								
Biscaldi 2016	390.59	26.5	18	381.97	15.1	33	17.6%	0.43 [-0.15, 1.01]
Cui 2010	0.795	0.11	12	0.79	0.135	29	15.9%	0.04 [-0.63, 0.71]
Matsuura 2014	0.19	1.36	11	0.27	1.43	19	14.7%	-0.06 [-0.80, 0.69]
Ring 2016	0.525	0.245	18	0.61	0.225	18	16.1%	-0.35 [-1.01, 0.31]
Trontel 2015	9.8	3	38	12.7	2.7	31	19.0%	-1.00 [-1.50, -0.49]
Urbain 2015	75.32	13.915	20	80.265	13.765	20	16.7%	-0.35 [-0.98, 0.27]
Subtotal (95% CI)			**117**			**150**	**100.0%**	**-0.23 [-0.67, 0.21]**
Heterogeneity: Tau² = 0.20; Chi² = 14.83, df = 5 (P = 0.01); I² = 66%								
Test for overall effect: Z = 1.04 (P = 0.30)								
14.3.2 LTM								
Blair 2002	25.764	3.392	12	25.016	3.024	12	11.6%	0.22 [-0.58, 1.03]
Bowler 2014	0.77	0.23	18	0.89	0.15	18	14.5%	-0.60 [-1.27, 0.07]
Chen 2016A	0.56	0.22	24	0.71	0.13	24	16.6%	-0.82 [-1.41, -0.23]
Lind 2014	0.67	0.24	20	0.75	0.19	20	15.6%	-0.36 [-0.99, 0.26]
Massand 2015	0.575	0.25	15	0.715	0.17	18	13.6%	-0.65 [-1.36, 0.05]
Renner 2000	0.95	0.07	14	0.94	0.07	14	12.8%	0.14 [-0.60, 0.88]
Souchay 2013	0.73	0.12	19	0.7	0.12	19	15.3%	0.24 [-0.39, 0.88]
Subtotal (95% CI)			**122**			**125**	**100.0%**	**-0.29 [-0.62, 0.05]**
Heterogeneity: Tau² = 0.09; Chi² = 10.49, df = 6 (P = 0.11); I² = 43%								
Test for overall effect: Z = 1.66 (P = 0.10)								



Test for subgroup differences: Chi² = 0.04, df = 1 (P = 0.85), I² = 0%

Supplementary Table 26 - Forest plot of subgroup comparison on visual free recall performance depending on LTM or STM between ASD people and TD controls

Study or Subgroup	ASD Mean	ASD SD	ASD Total	TD Mean	TD SD	TD Total	Weight	Std. Mean Difference IV, Random, 95% CI
14.4.1 STM								
Cui 2010	7.25	3.315	12	7.225	1.625	29	11.1%	0.01 [-0.66, 0.68]
Funabiki 2018	37.45	3.15	64	38.23	2.16	30	18.5%	-0.27 [-0.70, 0.17]
Garcia-Molina 2019	9.59	3.26	30	10.57	1.94	30	15.7%	-0.36 [-0.87, 0.15]
Geurts 2004	5	1.7	41	6.1	1.9	41	18.2%	-0.60 [-1.05, -0.16]
Trontel 2015	7.1	3.5	38	9.4	2.7	31	16.4%	-0.72 [-1.21, -0.23]
Verté 2005	5	1.9	61	6.7	1.5	47	19.9%	-0.97 [-1.37, -0.57]
Subtotal (95% CI)			**246**			**208**	**100.0%**	**-0.53 [-0.80, -0.26]**
Heterogeneity: Tau² = 0.05; Chi² = 9.51, df = 5 (P = 0.09); I² = 47%								
Test for overall effect: Z = 3.82 (P = 0.0001)								
14.4.2 LTM								
Funabiki 2018	15.98	3.32	64	17.23	1.74	30	16.8%	-0.43 [-0.86, 0.01]
Lopez 2008	9.735	3.13	15	11.995	1.94	16	9.6%	-0.85 [-1.59, -0.11]
Loth 2011A	32.2	12.2	25	33	10.1	20	12.7%	-0.07 [-0.66, 0.52]
Loth 2011B	25.8	9.7	13	29	7.6	14	9.3%	-0.36 [-1.12, 0.40]
Renner 2000	0.23	0.11	14	0.22	0.1	14	9.6%	0.09 [-0.65, 0.83]
Ring 2018	0.72	0.18	37	0.82	0.14	31	15.3%	-0.61 [-1.09, -0.12]
Trontel 2013	5.98	3.45	56	9.37	2.7	31	15.9%	-1.05 [-1.52, -0.58]
Williams 2012	13.69	3.46	17	13.79	2.78	17	10.9%	-0.03 [-0.70, 0.64]
Subtotal (95% CI)			**241**			**173**	**100.0%**	**-0.45 [-0.73, -0.17]**
Heterogeneity: Tau² = 0.07; Chi² = 12.95, df = 7 (P = 0.07); I² = 46%								
Test for overall effect: Z = 3.11 (P = 0.002)								

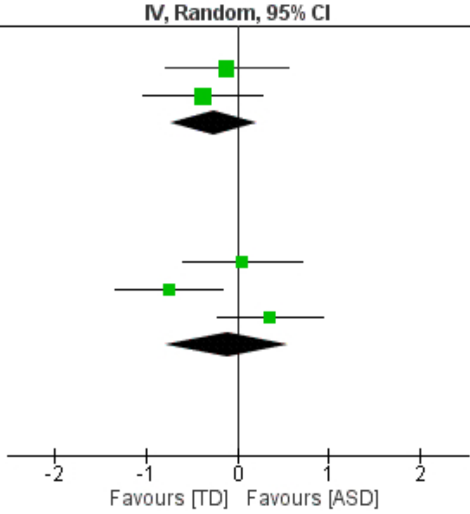


Test for subgroup differences: Chi² = 0.15, df = 1 (P = 0.70), I² = 0%

Supplementary Table 27 - Forest plot of subgroup comparison on visuo-spatial recognition performance depending on LTM or STM between ASD people and TD controls

	ASD			TD				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
14.5.1 STM								
Cui 2010	0.735	0.105	12	0.75	0.13	29	49.0%	-0.12 [-0.79, 0.55]
Ring 2016	0.5	0.22	18	0.58	0.19	18	51.0%	-0.38 [-1.04, 0.28]
Subtotal (95% CI)			**30**			**47**	**100.0%**	**-0.25 [-0.72, 0.22]**
Heterogeneity: Tau² = 0.00; Chi² = 0.30, df = 1 (P = 0.59); I² = 0%								
Test for overall effect: Z = 1.05 (P = 0.29)								
14.5.2 LTM								
Bowler 2014	0.26	0.34	18	0.24	0.39	18	31.8%	0.05 [-0.60, 0.71]
Cooper 2015	0.48	0.26	24	0.62	0.019	24	33.8%	-0.75 [-1.33, -0.16]
Ring 2015	0.21	0.11	25	0.17	0.11	23	34.3%	0.36 [-0.21, 0.93]
Subtotal (95% CI)			**67**			**65**	**100.0%**	**-0.11 [-0.78, 0.55]**
Heterogeneity: Tau² = 0.25; Chi² = 7.34, df = 2 (P = 0.03); I² = 73%								
Test for overall effect: Z = 0.33 (P = 0.74)								

Std. Mean Difference
IV, Random, 95% CI



Test for subgroup differences: Chi² = 0.11, df = 1 (P = 0.74), I² = 0%

Supplementary Table 28 - Summary of sensitivity analysis results. NH: No significant Heterogeneity between studies

	Meta-Analysis p-value	Sensitivity Analysis p-value
Comparison LTM vs STM		
Long Term Memory	**<0.001**	NH
Short Term Memory	**0.005**	**<0.001**

		LTM		STM	
		Meta-Analysis p-value	Sensitivity Analysis p-value	Meta-Analysis p-value	Sensitivity Analysis p-value
Type of material					
Visual		**<0.001**	**<0.001**	**0.005**	**<0.001**
Visuo-spatial				**0.002**	**<0.001**
Verbal		**0.01**	NH	**<0.001**	**<0.001**
Type of memory retrieval					
Recognition		0.16	NH	0.07	**<0.001**
Cued recall		0.58	NH		
Free recall		**<0.001**	NH	**0.004**	**<0.001**
Material and retrieval					
Verbal	Recognition	0.51	NH		
	Cued recall	0.58	NH		
	Free recall	**<0.001**	NH	**<0.001**	**<0.001**
Visual	Recognition	0.1	NH	0.3	0.79
	Free recall	**0.002**	NH	**<0.001**	**<0.001**
Memory organisation					
Serial				**0.009**	**<0.001**
Non-Serial memory				**<0.001**	**<0.001**
Associative		0.31	**<0.001**		
Non-Associative memory		**0.006**	**0.007**		
Semantic link		0.06	0.12		
Semantic link unrelated		0.62	0.35		
Additional Memory Control					
Plus additional cognitive control				**0.009**	**<0.001**
Without additional cognitive control				**<0.001**	**<0.001**