Exploring Spatial Memory in Children with Autism and ADHD

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Abstract

The study investigates spatial memory in neurotypicals, ASD and ADHD children. In a reaction-time accuracy task, children (*N* = 117) were presented with a grid containing twenty-five individual places. In the presentation phase, children saw different categories of object-in-places which varied from technical to social role play toys. An interference object which was either the same or a different-object exemplar filled the delay between the presentation and test. At test, children were required to recall the location occupied by the object. Among the clinical and matched control groups tested, comparatively better place memory accuracy was evident in ASD children; however this was accompanied by longer place memory reaction times. Same-object presentation in the delay was improving place memory accuracy and speeding up reaction times of children, in comparison to a different-object exemplar. Technical objects were better remembered by the mainly male sample than roleplay and neutral objects, but this particular category of objects had the slowest reaction times. When the binding strategies as per Common Region Test (CRT) were included in the analyses, place memory accuracy was more accurate among systematic coders than unsystematic coders. Interestingly, place memory accuracy and reaction times of those who adopted systematic binding benefitted more from repetition (same-object delay) than those who coded unsystematically – a pattern found across most object categories. Thus, one could say that the repetition was helping to reinforce the object-place binding among systematic coders.

Key Words place memory; object interference; repetition; spatial binding strategies

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1. Introduction

An integral element that forms part of our human functioning is recalling where things are (Hund & Plumert, 2003). In order to execute necessary tasks on a daily basis, such as cooking or even driving to work, one must have the ability to remember locations. The majority of these tasks require individuals to establish an association between objects and their respective locations. For instance, to make pasta it is not only sufficient to know that pesto, tomato paste, garlic, olive oil and cheese are needed, it is vital to know where the ingredients are located. In truth, if the object-location link is jeopardised, this may result in a lengthy exploration. This concept is applicable to visuo-spatial research, as studies test both object and location memory. Within this domain, overshadowing of places remains a concern, as this hinders spatial learning (Mackintosh, 1976; March, Chamizo & Mackintosh, 1992; Pearce, Graham, Good, Jones & McGregor, 2006; Sanchez-Moreno, Rodrigo, Chamizo & Mackintosh, 1999; Spetch, 1995). Historically, Pavlov (1927) described the term "overshadowing" in the context of stimulus intensity and saliency. He proposed that the effect of conditioning to a weak stimulus may be undermined if it was consistently paired with an intense stimulus. That is to say, conditioning to the weaker component would be overshadowed by the stronger component of a compound conditioned stimulus (CS). In this way, the more salient component will grab the majority of attention overshadowing conditioning to the less salient component. Hence, Pavlov explained this as competition between the two types of components. In the light of visuo-spatial research, places are overshadowed by objects or object shapes as they may be more salient for children, resulting in heightened attention toward the objects and not places per se.

Place learning (where-system) can often pose great difficulty for children, even if they accelerate during the experiment (Lange-Küttner, 2013). This is due to the fact that in comparison to object memory, place learning exerts a greater cognitive load (Remington, Cartwright-Finch & Lavie, 2014). In computerized tasks assessing object place and object shape memory, 5-to 6-year-old children remember object shapes over places (Lange-Küttner, 2010a; 2010b). This is clearly indicative of the fact that young children prioritize object shape processing, hence overshadowing places.

In fact, there may be a strong preference for certain objects over others in children. In accordance with the theory of the extreme male brain proposed by Baron-Cohen (2002; 2003), boys (versus girls) show a strong preference for technical toys such as vehicles, construction sets and lego. This type of preference is also referred to as intense or circumscribed interest which is one of the key diagnostic features in the symptomology of autism spectrum conditions (American Psychiatric Association, 1994; 2000; Wing, 1981). Therefore, the present study will explore and compare these interests further in children with Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD) and neurotypicals. It was hypothesised that especially children with ASD would show a strong content effect in an object/place memory task.

In the following sub-sections to this section, it will be explained (1) A rationale for testing place memory in ASD and ADHD children (2) An overview of the working memory (WM) memory model and related interference paradigms such as selective interference which tackle aspects of the WM model, for example, the visuo-spatial sketchpad (3) Further discussion of interference tasks such as ‘what’ and ‘where’ delays and their impact on place memory performance (4) A rationale for the covariates used in the present research.

The majority of previous studies within this domain have focused on normally developing young children (e.g. Huttenlocher, Hedges & Duncan, 1991; Hund & Plumert, 2002; Lange-Küttner, 2013; Lange-Küttner & Küttner, 2015; Schutte, Spencer & Schoner, 2003). Children with ASD versus ADHD are not directly compared with respect to spatial memory because the research concentrates more on the social deficits in ASD and ADHD

(DuPaul, McGoey, Eckert & Vanbrackle, 2001; McCracken et al, 2002). Thus, the current study will directly compare the two clinical groups, resp. ASD and ADHD children in a location memory task.

In working memory literature, a specialised visuo-spatial working memory has received considerable attention over the years (Logie, 2014). The working memory (WM) model (Baddeley, 1986; Baddeley & Hitch, 1974) explains the functions of working memory that are responsible for storing and processing both visual and spatial information.

The original working memory model comprises of three components. The first and most vital component is the central executive which is a system responsible for controlling attention. It ensures efficient and effective use of memory resources in order to achieve targets that have been set. In addition to this, the model consists of temporary storage systems, namely the phonological loop and visuo-spatial sketchpad. The phonological loop stores speech-based information and the visuo-spatial sketchpad stores visual along with spatial information. These systems are also referred to as ‘slave systems’ because they are merely responsible for holding information, playing a passive and not an active role per se. Despite the success of the original working memory model in experimental research (Baddeley & Logie, 1992), particular aspects of the model were flawed resulting in modifications. For instance, the model did not consider the link between working memory and long-term knowledge. As a consequence of such criticisms, Baddeley proposed a fourth component known as the episodic buffer (Baddeley, 2000). This component amalgamates information from the other systems, provides slightly extra storage capacity and takes into account long-term memory (LTM). Long-term representations of semantic and taxonomic knowledge could potentially be a route for specialist circumscribed interest to have an impact on memory for specific object-location binding.

According to the working memory model (Baddeley, 1986), the maintenance of visuo-spatial information is carried out via the visuo-spatial sketchpad. Together with the activity of the phonological loop, these slave systems are controlled by the central executive. Various facets of the phonological loop function in relation to working memory are understood in their entirety, whereas aspects of the visuo-spatial sketchpad are understood to a lesser degree (Logie, 1995). Research has shown that the phonological loop comprises of two distinct subcomponents, namely a phonological store and a rehearsal process (Baddeley, 1997; Baddeley, Gathercole & Papagno, 1998; Gathercole & Baddeley, 1993). On the other hand, the visuo-spatial sketchpad was seen as an integrative component of visual and spatial information. Nonetheless, light was shone on an opposing view stating that in fact two separable components are responsible for dealing with visual and spatial information, namely a “visual cache” and an “inner scribe” (Baddeley & Logie, 1999). The visual cache is responsible for dealing with visual information (visual slave system) such as colour and shape, as well as playing a contributory role in the visual perceptual system. The inner scribe governs information regarding movement (motor slave system). An approach testing the phonological loop and the visuo-spatial sketchpad includes the selective interference paradigm (Pickering, Gathercole, Hall & Lloyd, 2001; Logie & Marchetti, 1991), as discussed below.

In working memory research (Baddeley & Hitch, 1974), a widely used paradigm is the selective interference paradigm. The rationale is that two processes drawing on the same modality working memory sub-system should increase the cognitive load and thus interfere with optimal performance, while processes drawing on different modality working memory sub-systems would not hamper performance. For instance, Logie and Marchetti (1991) conducted an experiment with adults consisting of two interference tasks: visual interference (irrelevant pictures), as well as spatial interference (movements of the arm which were previously not seen). It was predicted that if the purpose of secondary tasks was to cause general performance impairment, then no specific effects of pairing similar primary and secondary tasks would be evident. If, however, two distinct subcomponents are responsible for dealing with visual and spatial information, the activity of both these components should be unaffected by a different kind of secondary task (versus those tasks that utilize the same resources). The interference tasks were presented for a duration of 10 seconds. Both the visual and spatial interference tasks lead to diminished performance on the primary task of a similar kind. Another study in which participants were required to remember the places of dots, together with shapes uncovered similar findings (Tresch, Sinnamon & Seamon, 1993). Other research has found that memory for object visual information is influenced by variants of visual noise such as, patterns of dots constantly flickering (Quinn & McConnell, 1996). In a dual-task paradigm, place memory is undermined by sequential tapping more than by squeezing a tube, that is, hand movements (Smyth & Pendleton, 1989). In support of this, Della Sala and colleagues (Della Sala, Gray, Baddeley, Allamano & Wilson, 1999) conducted a study where participants completed a visual interference task (looking at abstract paintings), resulting in performance impairment only when the primary task was a visual task and not a spatially loaded task. Earlier, an opposite pattern was observed for a spatially related primary task (Milner, 1971).

The distinction between spatial and visual working memory has been investigated previously in the literature using two specific kinds of tasks, namely the Corsi Blocks task and the Matrix Patterns task (Della Sala, Gray, Baddeley, Allamano & Wilson, 1999; Logie & Pearson, 1997; Salame, Danion, Peretti & Cuervo, 1998). The Corsi Blocks task has been linked to spatial working memory as it involves recalling a movement sequence, which requires encoding, maintenance and retrieval of the items in the sequence, as well as the order in which they appear. The Matrix Patterns task has been assumed to rely on visual working memory as participants are required to recall an abstract pattern that is created by filled squares in a matrix. Thus, this task involves a series of locations presented simultaneously rather than sequentially. In a study by Logie and Pearson (1997), the authors used the Corsi Blocks and Matrix Patterns task in order to investigate visual and spatial working memory development in children aged 5- to 12-years. Results revealed that memory span for the visual pattern was higher than the memory span for the spatial sequence and that this task difference became more salient with increases in age. Therefore, it was concluded that the pattern of results supported a developmental fractionation between visual (visual cache) and spatial (inner scribe) components within working memory. Research conducted prior to this also demonstrated a similar pattern of results (Orsini et al., 1987; Wilson, Scott & Power, 1987). In order to evaluate the findings of the Logie and Pearson (1997) study, executive components of working memory can be considered: Both visual and spatial span procedures placed extensive demands on children's working memory, hence the need to recruit executive control and attentional processes to support visuospatial task performance, likewise reflected in a study by Hamilton and colleagues (Hamilton, Coates & Heffernan, 2003). Nevertheless, other authors have argued that spatial and visual working memory tasks differ in the extent to which they rely on these executive processes. Authors have concluded that spatial working memory demands more extensive attentional control (e.g. Vandierendonck, Kemps, Fastame & Szmalec, 2004; Rudkin, Pearson & Logie, 2007).

Another variation of an interference task is using 'what' and 'where' system delay task. The what-and-where systems comprise of two modular processing systems. Thus, as the name suggests, a 'what' delay is thought to activate object processing, while the 'where' delay would activate location and movement processing (Fodor, 1983; Lange-Küttner & Friederici, 2000). In one such object and place memory experiment which adopted the what-and-where methodology, the what-delay influenced children's accuracy performance: When children took longer to judge the size of the animal, that is, whether it was big or small, an improvement in memory accuracy was noted. Furthermore, faster responses when completing the where-delay task lead to faster reaction times in the place test thereafter. Thus, children's memory performance benefitted from 'what' (appearance-reality) and 'where' (movement identification) delay tasks: While the what-delay task held significance for memory accuracy, the where-delay task was eminent for reaction times (Lange-Küttner & Küttner, 2015). In the current study, a new interference type of what-delay was administered in the hope to assess the effect of interference on place memory performance of ASD, ADHD and typically developing children. During the delay task, children either saw the same object (same-object delay) identical to that seen in the presentation phase or a different object (different-object delay) which was an exemplar of the same category. The rationale for this new interference type was that the repetition of the same object would strengthen the representation of this object in episodic and probably long-term memory.

Therefore, the present research investigates whether children's place memory is facilitated by seeing the same object again versus a different object exemplar during the delay. On the one hand, same-object delay taps into the mechanism of repetition which often works to the advantage of children's place memory performance, whether this is obvious to them or not. For example, in the study by Lange-Küttner and Küttner (2015), the authors concluded that repeatedly viewing the object in the same location resulted in profound place learning. Moreover, even just straightforward stimulus repetition without place information had a powerful general facilitation effect on memory formation and learning in children (Bauer, 1997; Ihssen, Linden & Shapiro, 2010). On the other hand, a different object exemplar in the delay would have a somewhat disruptive effect as it would require a dissociation of the specific object-place binding already established in the presentation phase. Moreover, the extent to which a different object exemplar influences children's place memory performance may also depend on how well they can control for interference. For example, Geurts and colleagues (2004) found that among children with high-functioning autism, interference control was not impaired (Geurts, Verte, Oosterlaan, Roeyers & Sergeant, 2004). Conversely, another study concluded that children with ADHD had weaker interference control compared to typically developing children (Mullane, Corkum, Klein & McLaughlin, 2009). Therefore, the sample of ASD children (versus ADHD children) in the current study may be interfered by a different object exemplar to a lesser degree.

In the present research, specific variables were taken into account as existing literature is indicative of their association with spatial memory. Firstly, age as a covariate was considered. Over the years, a conclusive body of evidence has emerged in support of the link between spatial memory and age (Bayliss, Jarrold, Baddeley, Gunn & Leigh, 2005; Cestari, Lucidi, Pieroni & Rossi-Arnaud, 2007, Klingberg, 2006). For example, Cestari and colleagues (2007) concluded that as children's age increased from 6-, 8-, to 10-years, there was an improvement in spatial memory across all three task conditions: positional encoding, object-place binding and a combination of the two. These age-related improvements in spatial working memory were likewise evident in ASD children. In one such study, the authors found that young individuals with ASD made more errors on spatial working memory tasks, while older individuals with ASD did not (Happe, Booth, Charlton & Hughes, 2006). The second factor considered was IQ. A study conducted by Colom and colleagues (2004) found that working memory was almost perfectly predicted by general intelligence: Confirmatory factor analyses produced high estimates of the loading of general intelligence over working memory, with an approximate value of 0.96 (Colom, Rebollo, Palacios, Juan-Espinosa & Kyllonen, 2004). In another study, the authors identified a strong relationship between working memory and fluid intelligence (Unsworth, Fukuda, Awh & Vogel, 2014), which in the present study is assessed via the Raven. Furthermore, place memory was also controlled for visual-motor integration skills. Research conducted by Englund, Decker, Allen and Roberts (2014) found a visual-motor integration deficit among children with ASD and ADHD (versus matched controls), which may impact spatial memory accuracy and reaction times of the clinical sample in the current study. The final variable taken into account was children's spatial binding strategies, measured by the Common Region Test (CRT) (Lange-Küttner, 2006). Research has shown that the CRT is a predictor for spatial memory: On the one hand, objects-area binding predicts enhanced location memory and on the other hand, object-place binding predicts enhanced object memory (Lange-Küttner, 2010a, 2010b, 2013).

The following sub-sections will explain (1) Spatial binding strategies such as object-place coding, objects-area coding and unsystematic coding in relation to their effect on place memory (2) The eminence of measuring reaction times in visuo-spatial research (3) The prevalence of intense and circumscribed interests in neurotypicals and autistic children (4) Discussion of the weak central coherence theory: A characteristic possessed by children with autism (5) The prototype account of object categorization (6) The impact of spatial cues such as explicit grid boundaries and landmarks on place memory performance (7) Development of spatial memory and how it is acquired (8) How delay tasks influence memory for locations (9) A theoretical overview of what the current study entails and the hypotheses under investigation.

1.1. Spatial Binding in Place Memory

Visual memory and attention can be influenced by spatial binding processes. The spatial binding approach describes the manner in which a particular object is embedded into a spatial context (Brown & Warburton, 2006; Lange-Küttner, 2008; Treisman, 2006; Treisman & Zhang, 2006). The two types of spatial binding are objects-area versus object-place binding (Edgin, Spano, Kawa & Nadel, 2014; Hsieh, Gruber, Jenkins & Ranganath, 2014). One method adopted to investigate spatial binding in children is the use of a drawing task, known as the Common Region Task (CRT) (Lange-Küttner, 2006). The task consists of three rows of dots, which either were all the same at the same distance, or pairs of dots showed visual similarity or proximity (Palmer, 1992). In objects-area binding, these pairs are associated with an area in space, whereas in object-place binding, a particular object is associated with a place. The latter takes place earlier in a child's development than the former (Lange-Küttner, 2006, see Fig. 1; Uttal & Chiong, 2004). In one such study assessing perceptual grouping among children with ASD versus mental-and chronological-age matched typically developing children, it was found that children with ASD compared to neurotypicals largely grouped by proximity and lesser by similarity (Falter, Grant & Davis, 2010).

The Common Region Test (CRT) measures spatial binding and is predictive of visual memory: Objects-area binding predicts enhanced location memory among 7-to 10-year-old children (systematic learning), whereas object-place binding predicts enhanced object memory among 4-to 6-year-old children (Lange-Küttner, 2010a; 2010b; 2013). There is also unsystematic coding, where children use a combination of objects-area and object-place binding approaches. Hence, the CRT is a useful tool to assess children's spatial binding strategies that is also used in the present study.

An intriguing finding is the facilitating priming effect of seeing a grid (type of array in which individual places are denoted by spatial boundaries) on place memory, which provided the same facilitation as children's spatial binding approach (Lange-Küttner, 2010b). Thus, in children, place memory is facilitated by the presence of explicit spatial boundaries, either provided externally or by internal concepts. In spatial arrays with many shapes, the presence of spatial boundaries delimiting spatial regions can be facilitating (Lange-Küttner, 2013). However, this may pose a difficulty for children with ADHD since they are less likely to confine their visual attention (Shalev & Tsal, 2003).

Why should encoding a region be helpful to place memory? A region may act as a place memory facilitator because of its requirements to form a visual pattern based on shapes (De Ribaupierre & Bailleux, 2000; Uttal & Chiong, 2004). Memory for visual patterns excels during middle childhood upon the simultaneous presentation of stimuli, but memory formation is slower when visual patterns gradually form from a one-by-one sequence of stimuli (Logie & Pearson, 1997; Pickering, 2001; Pickering, Gathercole, Hall & Lloyd, 2001; Schumann-Hengsteler, Strobl & Zoelch, 2004). In previous research (Hund & Plumert, 2003), spatial memory for many object locations in a common area were tested. However, in the current study, spatial memory for just one object-in-place was tested. Children actively pointed to the location without a shape being present in the test. Therefore, children needed to remember one object in an area, not a group, whether simultaneous or sequential. Hence, one could infer that this study is testing object-place and not object-area binding per se.

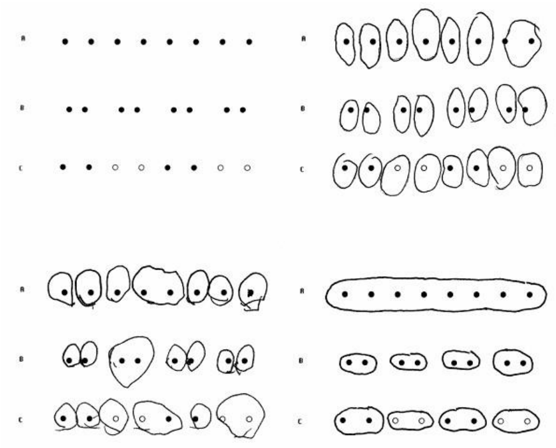


***Figure* 1 Spatial Boundaries Drawn by Children in the Wertheimer array of dots** (Common Region Test is illustrated on the upper left). Young children, typically between the ages of four and six years' show object-place binding (upper right), however as age increases object-region binding dominates (lower right). A small proportion of children are unsystematic coders (lower left) (Lange-Küttner, 2006).

1.2. Measuring Reaction Times for Place Memory

Spatial exploration is an ability during which information is obtained which remains important throughout an individual's life. This ability is dependent upon two factors:

curiosity and stimulus salience (Wright & Vlietstra, 1975, p. 201). Another parameter that plays an eminent role in spatial learning is speed. Speed, when tested in different environments was affected by anxiety and novelty. Heightened anxiety lead to increased speed, while changes in the array lead to increased exploration (Wells et al., 2013). Among 2-year-old infants, insecurity was related to decreased spatial exploration (Stupica, Sherman & Cassidy, 2011). In visual memory experiments, children showed higher reaction time acceleration during place recognition than adults in each successive memory block in the visual memory experiment. However, while children's reaction times accelerated, their place memory accuracy did not improve (Lange-Küttner, 2013).

Initially, accuracy was used to measure children's spatial cognition (Hund & Plumert, 2005; Liben, 1988; Newcombe & Huttenlocher, 2003; Piaget & Inhelder, 1956), however in recent years, more emphasis has been placed on measuring reaction times in children (Kosslyn, Margolis, Barrett, Goldknopf & Daly, 1990; Lange-Küttner, 2012; Portrat, Camos & Barrouillet, 2009). High correlations have been found between computerized memory tasks and academic performance, since less compensatory strategies and manoeuvres are required (Lepine, Barrouillet & Camos, 2005). Nonetheless, in a mental rotation task, training children to perform as fast as adults resulted in item-specific learning (Kail & Park, 1990), that is, learning to rotate one object did not transfer to another object. Moreover, speed of reaction times can overshoot in children, but this may be independent of their place memory accuracy (Cowan et al., 2006; Lange-Küttner, 2013). This usually occurs because after making an error, children do not slow down (Sokhadze et al., 2010; Vlamings, Jonkman, Hoeksma, van Engeland & Kemner, 2008). This reaction-time accuracy trade-off is commonly observed in children as they usually can improve either reaction times or accuracy, that is, only one can be trained but not both (Mackey, Hill, Stone & Bunge, 2011). Cowan and colleagues (2006) shone a light on the notion that children's reaction times were reflective of their ‘comfortable’ pace, as opposed to the maximum speed within their capacity. However, when children are presented with more demanding visuo-spatial memory tasks, reaction times do accelerate (Lange-Küttner, 2012; 2013). There are also gender differences in children’s speed. In spatial tasks such as the Embedded Figures Task (EFT) and mental rotation (MR), reaction times in boys could be measured reliably according to task difficulty, whilst this was not possible in girls who worked at their own pace irrespective of the kind of task (Lange-Küttner & Ebersbach, 2013).

Speed also plays a crucial role in spatial binding. In one such study involving 55,753 individuals, aged between 8 and 75 years, it was found that those individuals with a slower information processing speed (young children and aged adults) displayed difficulties when associating objects with places (Brockmole & Logie, 2013). Information processing speed undergoes age-related changes; speeding up particularly after commencing school (Kail, 1995; 2000) and this drives performance in various tasks (Kail, 1996). As highlighted in a model representing spatial memory and speed, there are two ways in which place learning can occur: fast but long-lasting storage of episodic information versus slow formation of spatial relations (McClelland, McNaughton & O’Reilly, 1995; O’Reilly & Rudy, 2000; 2001). The latter is a slower process since the integration of spatial relation memories are experience-dependent, hence they are probabilistic and overlap in terms of quality (Norman & O’Reilly, 2003). Conversely, episodic memories are faster to learn due to their specificity. This coincides with the encoding-specificity effect which posits that memory is facilitated when the presentation and test completely overlap with one another (Godden & Baddeley, 1975).

1.3. Intense Interests in Typically-Developing and Autistic Children

Circumscribed interests are a captivating phenomenon in children with autism spectrum disorders (ASD). Significant proportions of children with ASD as well as typically developing (TD) young children become intrigued with certain objects or categories of objects. Many times, children exhibit a passionate and sometimes obsessive attraction to particular categories of objects that interest them (DeLoache, Simcock & Macari, 2007). These extremely intense interests mirror the circumscribed interests and preoccupations displayed by those children with ASD (Lord, Rutter & Le Couteur, 1994; Baron-Cohen & Wheelwright, 1999). In the symptomology of ASD, obsessional and circumscribed interests (CI) are an eminent diagnostic feature (American Psychiatric Association, 1994; 2000; Klin, Pauls, Schultz & Volkmar, 2005; Klin, McPartland & Volkmar, 2005; Szatmari, 1991; Wing, 1981), affecting a larger number of males than females (Baron-Cohen, 2002). These interests are an under-studied phenomenon, relative to other key diagnostic features such as social development and communicative impairments (Klin, Danovitch, Merz & Volkmar, 2007; Brown, Lam, Holtzclaw, Dichter & Bodfish, 2011). One such research was conducted by Baron-Cohen and Wheelwright (1999) with ninety-two children who had ASDs. The aim of the study was to explore the content of these intense interests via a survey completed by parents. Results indicated that amongst the ASD population, obsessions were more pronounced in the realm of “folk physics” (84%) in comparison to “folk psychology”. That is to say, individuals with ASD, who were in the majority boys, had a stronger preference for vehicles, computers and machines (mechanical items), as opposed to relationships, desires, gossip and beliefs. Parallel with this finding, South, Ozonoff and McMahon (2005) reported common circumscribed interests manifested by individuals with ASD, namely trains, vehicles, electronics, planes, numbers, sporting equipment and certain animals. Other research (Brown, Lam, Holtzclaw, Dichter & Bodfish, 2011) supported these findings, revealing that ASD participants (versus typically developing children) displayed an intense interest in technical systems (non-social in nature). These findings suggest the prevalent nature of intense and circumscribed interests in autistic children is not in the social domain

(Smith et al., 2009; Lam, Bodfish & Piven, 2008). Moreover, these interests are not an exception but are viewed as the norm (Klin, Danovitch, Merz & Volkmar, 2007): 75% and 88% (children:adolescents) of a higher functioning ASD sample possessed intense interests. Taking into account these mechanical object preferences found among ASD children, it was hypothesised that this clinical sample would show a strong content effect in the object/place memory experiment of the current study, reflected by higher accuracy scores for the location memory of the technical objects in comparison to the roleplay and neutral object categories.

A study designed to investigate the impact of circumscribed interests on patterns of visual attention in children and adolescents with ASD found that images related to “High Autism Interest” (HAI) objects attracted heightened visual attention, thus increased perservative attention and diminished exploratory behaviour of social images (Sasson, Brown, Holtzclaw, Lam & Bodfish, 2008). When HAI images were not presented, no difference in visual attention patterns was detected between ASD and typically developing children. This finding suggests that children with ASD exert extra energy on circumscribed interests which play a crucial role in fixations in visual attention. Consistent with this finding, Sasson and colleagues (2011) reported that children with autism (2-to 5- year-olds versus age-matched TD children) exhibited increased exploration and attention towards images relating to their interests such as trains and vehicles (Sasson, Elison, Brown, Dichter & Bodfish, 2011). The existence of these attention biases may hinder social information processing development (Sasson, 2006; Schultz, 2005; Koegel & Covert, 1972).

Likewise, research has evolved to show that intense interests are a characteristic shared by some typically developing (TD) children, dominating the lives of boys more than girls (DeLoache, Simcock & Macari, 2007). DeLoache and colleagues (2007) revealed that the content of young children’s extreme interests included items that were highly stereotypical such as trains, vehicles, dolls, books, balls and dinosaurs; infrequent items were puzzles, tools and tea sets, together with idiosyncratic items such as Blue Angels and pouring liquids. Approximately 75% of the sample with intense interests were boys. Thus, also amongst TD children, a preponderance of boys is found, like in children with autism spectrum disorders (ASDs) and Asperger's Syndrome (Yeargin-Allsopp et al., 2003; Rutter 1978). A common behaviour reported by parents was that their child would express their interest by enthusiastically pointing to the objects of preference. This usually occurred in boys who showed intense interests in trains, cars and airplanes. Gender differences were observed in relation to the content of these intense interests. Amongst boys, half of the extreme interests (50%) reported fell into the following categories: trains, machines and vehicles and a further 27% for tools, dinosaurs and balls. Comparatively, intense interests of girls' (46%) included dolls, dressing up and tea sets. These findings were congruent with frequently reported gender-stereotyped categories of toy choice (Maccoby, 1998; O'Brien & Huston, 1985). Additionally, these gender differences were also reported in a longitudinal study, in which cars, trains, construction vehicles and trucks (conceptual domains) were amongst the dominant interests in boys (in 86% of the boys' sample), whereas manifestations in girls' were dolls, pretend play and creative interests (66%) (Johnson, Alexander, Spencer, Leibham & Neitzal, 2004). Already infants as young as 12-to 18-months display strong gender-stereotyped visual preferences. Boys tend to look longer at images of vehicles, while girls show this looking response in relation to dolls (Serbin, Poulin-Dubois, Colburne, Sen & Eichstedt, 2001). It is important to note that in the majority of studies discussed above, manifestations of intense interests were found among young TD boys between the ages of 11 months and 6 years, whereas the present study employs a much older sample of TD children, thus providing an extension of previous research.

Gender differences found in the content and incidence of intense interests coincide with the views of Baron-Cohen (2002; 2003). These interests in boys are seen as a prime example of systemizing which involves focusing attention towards constructing, analyzing and organizing particular domains or lawful and deterministic systems. While males scored higher in systemizing, females showed heightened empathising. Applications of systemizing include technical and mechanical systems such as vehicles, construction sets and computers to name a few. A study by Jennings (1977) found that boys (versus girls) showed a stronger preference for weapons, buildings blocks and vehicles which are all technical. Kimura (1999) reported that boys are highly interested and attentive in play where lego is involved. Through construction and reconstruction, lego bricks can be built into multiple systems. According to clinical reports, also boys with autism and Asperger's Syndrome show extreme preferences for mechanical toys (Baron-Cohen, 2002). A study reported that boys as young as one-year-old preferred watching videos of vehicles such as cars driving past, as opposed to watching a video with human faces. The opposite was true for girls (Lutchmaya & Baron-Cohen, 2002). In fact, even newborn baby boys showed a stronger preference, that is, looked longer at mobiles than human faces, while the opposite was applicable for girls (Connellan, Baron-Cohen, Wheelwright, Batki & Ahluwalia, 2000).

Nonetheless, in a study by Escudero, Robbins and Johnson (2013) which investigated innate versus learned nature of these gender-related preferences, infants aged 4 and 5 months and young adults were presented with images of doll faces and faces of real men and women, along with pictures of toy objects and real objects such as cars. In the presentation trials, participants saw face-object pairings. Interestingly, infants did not display gender-related preferences: They showed an indistinguishable preference for real and doll faces of men and women. Likewise, gender-related preferences for adults were not found when a comparison between social and non-social stimuli was made. However, adults displayed a stronger preference for opposite sex faces versus objects. Thus these findings question the notion that gender-linked preferences have an innate basis, indicating that preferences emerge due to maturation and social development when progressing into adulthood.

1.4. Weak Central Coherence in Autism

Frith (1989) held a firm belief that the assets and deficits observed in individuals with autism share a mutual origin, whereby those with autism are characterized as having weak ‘central coherence’. Central coherence is the term postulated to describe the tendency in typically developing individuals to incorporate diverse information in order to establish higher-level meaning in a contextualized manner. However, this is often accompanied by a lack of attention and memory for details. A representation of this shines through Bartlett’s work who conducted a battery of experiments in which individuals were required to recall images and stories. He found that individuals had better memory for the gist of a story, whereas retaining and recalling details posed difficulty (Bartlett, 1932). Surprisingly, this characteristic of global information processing is already evident in three-month old infants (Bhatt, Rovee-Collier & Shyi, 1994; Freedland & Dannemiller, 1996). Frith proposed that this information processing feature was disrupted among individuals with autism spectrum disorders (ASDs). People with autism tend to display a detailed-focused and local processing bias, that is to say, they place greater emphasis on retaining featural information, but fail to “see the bigger picture” and contextual meaning (Frith, 1989). Autistic children and adults show preoccupations with features, which is listed in the diagnostic criteria for the disorder (American Psychiatric Association, 1994), as well as conforming to Kanner’s notion of the “inability to experience wholes without full attention to constituent parts” (Kanner, 1943, p.220). In accordance with this cognitive theory, it was therefore predicted in the current study that individuals with autism (versus ADHD and typically developing children) will exhibit heightened performance on the place memory task as it requires attention to individual places which form part of a grid.

A growing body of research successfully demonstrated and supported the hypothesis that autism entails detail-focused enhanced perceptual processing (Mottron, Dawson, Soulieres, Hubert & Burack, 2006), which is also known as weak central coherence (Happé & Frith, 2006). This local enhancement is accompanied by a difficulty in establishing part-whole relationships, or just taking advantage of ready-made higher order chunks already present in the stimulus array (Mammarella, Giofre, Caviola, Cornoldi & Hamilton, 2014). In a well-known study by Shah and Frith (1983), autistic subjects (versus learning disabled and typically developing children, chronological and mental age matched) participated in the Children's Embedded Figures Test (CEFT). The test entailed children searching for a small figure within a larger nonsense design, indicating their response by tracing the figure or using a cut-out figure in this nonsense context. The maximum possible score was 25, with autistic children achieving a mean of 21 correct responses, in comparison to the control groups who obtained scores of 15 or less. The scores reflected by the control groups were indicative of the predominance of the gestalt (Gottschaldt, 1926). Better performance amongst autistic subjects reflected an advantage in locating objects and the ability to notice small changes in known layouts. In line with these findings, Jolliffe and Baron-Cohen (1997) reported that high-functioning autistic individuals, including those with Asperger's Syndrome, excelled on the Embedded Figures Test (EFT). This superior performance may result from minimal distraction by the camouflaged gestalt of the shape as a consequence of reduced part-whole integration, or enhanced local processing. Gestalt psychologists believed that resisting to see a gestalt over constituent parts was truly effortful (Koffka, 1935). However, this did not appear strenuous for children with autism and was viewed as an islet of ability (Shah & Firth, 1993). Contrary findings were revealed by Brian and Bryson (1996) who were not successful in finding this superiority effect on the EFT in autism.

Interestingly, in a study investigating whether spatial abilities would predict spatial drawings, heightened performance on the EFT was also evident in typically developing boys versus girls (Lange-Küttner & Ebersbach, 2013). Thus, superior performance on the EFT can also be explained by a general attentional mechanism. Research found that children with autism versus typically developing and intellectually impaired children took longer to respond when a small crosshair followed a large crosshair stimulus, whilst the opposite was not true (Mann & Walker, 2003; Rinehart, Bradshaw, Moss, Brereton & Tonge, 2001). The debate whether children with autism show superior attention to detail, or whether there is a weakness to process and take advantage of chunked global stimuli is still on-going (Simmons & Todorova, 2018).

Another elegant demonstration for testing visuo-spatial abilities, in relation to weak coherence was presented in another study by Shah and Frith (1993) who used the Wechsler Block Design subtest (Wechsler, 1974; 1981), a test proven to favour 3D segmentation abilities of those with autism (Frith & Happe, 1994). This task involves putting together puzzle pieces with geometric patterns to enable reconstruction of the initial design as in the model. The designs possess profound gestalt qualities, hence there are difficulties encountered when breaking up the design (Kohs, 1923). Shah and Frith found that typically developing and intellectually impaired individuals benefitted from pre-segmented design models, whereas a substantial advantage was observed in autistic subjects when only whole designs were presented. These results suggest that better performance of autistic subjects was reflective of their spatial segmentation skills (Lockyer & Rutter, 1970; Prior, 1979). Consistent with these findings, Ropar and Mitchell (2001) likewise used the Block Design and EFT to successfully evidence this superiority effect, marked by excelled performance for the autistic group, relative to subjects with Asperger's Syndrome.

Furthermore, other studies have validated the existence of a local advantage using the Navon task (Plaisted, Swettenham & Rees, 1999; Rinehart, Bradshaw, Moss, Brereton & Tonge, 2001; Navon, 1977). This task is also used to show the dominance of the overall form over constituent parts in young children. A study using the Navon Figure (Lange-Küttner, 2000) revealed that young children omitted the parts altogether when copying the figure. Therefore, it seems as though children are able to memorize parts (Elkind, Koegler & Go, 1964), however, they tend to selectively omit elements if allowed. These findings can be extended to samples of brain-damaged children (Stiles & Thal, 1988): The development of those children with left hemisphere lesions seems to be arrested, as their drawing procedures are similar to young children, whereas development of those children with right hemisphere lesions seems to be deviant. Although they can represent a whole, as well as parts, this is accompanied by distortions.

Moreover, in copying tasks, children with ASD (versus control groups) reflect a detail-focused drawing style by producing a greater number of local features (Mottron, Belleville & Menard, 1999; Booth, Charlton, Hughes & Happe, 2003; Mottron & Belleville, 1993). This was also evident in typically developing girls, but not boys: When drawing two occluding cubes, girls used a small-scale approach that capitalizes on details (object design detail). On the other hand, boys were more fixated on the silhouette of an object and perceived the cubes in a contextual manner, that is, the overall gestalt (Lange-Küttner & Ebersbach, 2013). Evidence from children with congenital focal brain injury showed that children with right hemisphere lesions demonstrated an integrative deficit when their drawing ability was tested. In drawing houses, these children produced the relevant parts of a house, but were unable to arrange them in a spatially organized manner, resultant from weak part-whole integration (Stiles, Janowsky, Engel & Nass, 1988). This deficit was not observed in children with left hemisphere lesions.

With reference to weak central coherence, tasks which favour the processing of features over wholes are viewed as advantageous for autistic children as reflected by their excelled performance on spatial tasks, so would it be plausible to conclude that tasks requiring contextual and meaningful interpretations of stimuli would be more difficult? A fascinating example is face processing, which consists of a combination of configural and featural processing (Tanaka & Farah, 1993). The inversion effect of faces seems to interfere only with configural processing among individuals with ASD (Bartlett & Searcy, 1993; Rhodes, Brake & Atkinson, 1993; Hobson, Ouston & Lee, 1988; Langdell, 1978). Deficits were also found in contextual disambiguation, including homographs (Frith & Snowling, 1983; Happe, 1994; 1997; Jolliffe & Baron-Cohen, 1999), inferior recall for related items compared to unrelated items (Tager-Flusberg, 1991) and diminished memory for sentences, but not for word strings (Jolliffe & Baron-Cohen, 2000; Hermelin & O'Connor, 1967). This shows that children with ASD are good in processing non-sense information. The research reviewed so far indicates that weak central coherence in autism is a processing preference and cognitive style, reflecting a trade-off between global (meaningful) versus local (piecemeal) processing, together with reduced meaningful integration which may be regarded as an impairment.

Moreover, another dominating clinical feature found in ASD which can be explained by weak central coherence is the prevalence of savant skills. In the domain of music, it has been reported that autistic children, who knew little about music, were better at learning note names for pitches, in comparison to the controls (Heaton, Hermelin & Pring, 1998). Other research has focused on local processing in graphical talent (Mottron & Belleville, 1993). Pring, Hermelin and Heavey (1995) used a modified Block Design task, consisting of meaningful scenes and geometric Wechsler designs. They found that artistically skilled, normally developing children (versus ASD children) were faster at drawing meaningful scenes rather than a detail-by-detail drawing style found in ASD children. In a longitudinal study exploring the emergence of realistic contours in relation to drawing human figures, findings revealed that the skill of drawing visually realistic contours requires an increase in conceptual processing toward the spatial layout and outer contour of the silhouette figure as a whole (Lange-Küttner, Kerzmann & Heckhausen, 2002).

Weak central coherence explains advantages and drawbacks alike, hence this balance (preferential processing for segments versus wholes) can manifest itself as a cognitive style at the expense of integrative processing. This can be elucidated using a continuum approach, in the light of brain-damaged children. Research has shown that children with right and left hemisphere lesions show deficits in spatial functioning (Stiles & Thal, 1988), whereby those individuals with left hemisphere lesions tend to focus on the whole and ignore details of spatial patterns. On the other hand, individuals with right hemisphere lesions focus on parts of a spatial pattern ignoring the whole. Therefore, autistic children adopt a right brain learning style and neurotypicals have a left brain learning style, with part-whole integration in the middle of these two extremes.

1.5. The Prototype Theory of Object Categorization

The term “categorization” is used to describe the process in which distinguishable objects are assigned to classes. Objects which belong to the same class are treated equivalently (Mervis & Rosch, 1981). This is an adaptive ability as it reduces numerous potential discriminations to a level that is more manageable, as well as allowing recognition and classification of novel stimuli (Bruner, Goodnow & Austin, 1956). In the current study, we initially defined ten categories of objects which were then collapsed into four categories and eventually three main object categories for analytical purposes.

When discussing research relating to category acquisition in children and adults, the prototype theory comes to mind and has received much attention over the years (Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976; Rosch, 1999). Research has shown that children automatically form prototypes during the first year of life (Younger, 1990). This theory postulated that as children are exposed to ill-defined category members, they are better able to identify and extract the central tendency of these object exemplars (Farah & Kosslyn, 1982; Scholnick, 1983). Hence, the prototype representation would consist of common features found among members of the particular category, together with an object that resembles the prototype which could be used as a reference object in the process of categorization. The prototype account seems convincing for children considering their limited verbal and visual working memory span, compared to the higher memory span of adults (Hitch & Halliday, 1983). As a result, children's categories contain a comparatively smaller number of defining attributes (Alexander & Enns, 1988). Prototype formation enables reduction in the volume of item-specific information that is stored for the purpose of category representation. In the present study, initial formation of the object categories as well as further category aggregation was based on featural and functional (prototypical characteristics) similarities between objects.

As noted above, children possess the ability to abstract prototypes. Empirical support for this notion originates from research which clearly depicts that this ability is hugely reliant upon the perceived typicality of an object in relation to a given category. In one such study conducted on a sample of 9- to 11-year-old children, it was found that all children took longer to substantiate category membership of an atypical object compared to that of a typical object (Bjorklund & Thompson, 1983). Consistent with this finding, other studies utilizing natural (Anglin, 1986) and artificial object categories (Mervis & Pani, 1980) revealed that even 5-year-old children verify typical objects more rapidly as opposed to those objects which are less representative exemplars. The effect of exemplar typicality was also investigated in high-functioning children, adolescents and adults with autism and matched neurotypicals between the ages of 9-to 48-years. A category verification procedure was adopted, measuring both accuracy and reaction times. Heightened processing among all age groups was evident for typical category exemplars versus atypical exemplars. Nevertheless, individuals with autism had slower reaction times compared to matched controls when verifying atypical exemplars – a pattern found across all age groups of autistic children (Gastgeb, Strauss & Minshew, 2006).

Furthermore, the initial object category exemplars generated by 5-, 8-, and 10-year-old children were the most common exemplars of their categories as reported by adults (Rosner & Hayes, 1977). Another study by Posnansky and Neumann (1976) tested 8- to 11-year-old children using an adaption of the recognition memory task. The authors aimed to investigate the formation of prototypical representations when children were presented with picture sets and letter trigrams. Results showed that across all age groups, confidence of recognition was a decreasing function of distance from the modal prototype. In other words, even children as young as eight years of age demonstrated the ability to configure prototypical representations. The research discussed is reflective of the fact that at a young age, children tend to generalize object properties. That is to say, members of a category share similar attributes to the category prototype.

This leads to the question of whether children with autism can successfully abstract a prototype. A study comparing rule-based categorization with prototype-based categorization revealed that autistic children, children with Down syndrome and neurotypicals performed indistinguishably on the rule-based categorization task. Nonetheless, on the prototype-based task where children were required to abstract a prototype of animal-like categories, autistic children and those with Down syndrome (versus neurotypicals) were unable to form a prototype (Klinger & Dawson, 2001). Therefore, the study concluded that children with ASD may have prototype impairment, likewise reflected in other research (Klinger & Dawson, 1995; Plaisted, 2001). However, studies have found opposite findings (Molesworth, Bowler & Hampton, 2005; 2008). The study by Molesworth and colleagues (2008) which used the same methodology as Klinger and Dawson (2001), found that higher-functioning autistic individuals demonstrated intact prototype formation. In fact, even when autistic children showed impaired generalization, prototype formation was still intact (Froehlich et al., 2012). Additionally, Tager-Flusberg (1985) tested the ability of autistic, mentally retarded and typically-developing children to categorize pictures from basic level and superordinate level categories. A matching-to-sample procedure was used. Performance did not differ among the three groups of children. Basic level categorization was not as effortful for children as abstract categorization, with prototypically aiding superordinate level categorization, that is, all children made an increasing number of errors when categorizing peripheral exemplars. Results also demonstrated that children with ASD had organized lexicons and they acknowledged the meaningful relationships among words at a superordinate level. The findings indicate that children with ASD do not lack the ability to categorize and are able to form abstract concepts. These contradictory results may be the result of differences in methodology and the varying functional levels of ASD children.

Limited research has been conducted examining category acquisition in children with ADHD. In one such study (Huang-Pollock, Maddox & Tam, 2014); the authors investigated the acquisition of explicit rule-based (RB) and associative information integration (II) category learning among school-aged ADHD children. All participants completed a task in which they were required to make a judgement on whether the object images belonged in category A or category B. In other words, the requisite of the task was to classify the stimuli. Results revealed that ADHD children (versus controls) exhibited impairments in both the rule-based paradigm and category learning. Children with ADHD tended to sort the object images by the more salient but irrelevant dimension, together with failing to adopt a consistent sorting strategy when classifying the stimuli. Findings suggest that these deficits reflect a reduction in the ability to utilize multiple features in order to categorize objects.

Research evidence also suggests that children's categorical judgments may be governed by specific exemplar information. The central idea of specific exemplar models is that object categorization depends upon memory traces of previously encountered category exemplars (Hintzman & Ludlam, 1980; Medin & Schaffer, 1978; Nosofsky, 1988). Therefore, when children are presented with a novel stimulus, categorization takes place via a comparison between the novel item and one or more of the encountered exemplars. Children are able to identify and classify the category prototype as it is similar to many category members, thus its increased likelihood to access stored exemplars. The prototype may also act as a retrieval cue for exemplar information, due to the fact that individual exemplars undergo time dependent memory decay (Hintzman & Ludlam, 1980). In the place memory experiment of the current study, all children completed a filled delay task testing the effect of same-object delay versus different-exemplar delay. It was predicted that the same-object delay would benefit place memory performance via repetition, but would the different-exemplar delay act as a true distractor or will children be able to use exemplar-specific information to recognise the category instance?

In one such study with a sample of 7-year-old children and adults, the authors (Tighe, Tighe & Schecter, 1975) aimed to investigate memory development of exemplar-specific information and categorical properties of words. Both children and adults were required to sort these words into two categories. For some participants the recognition memory test was administered immediately after, whilst for others there was a 3-week delay. Participants were required to identify the test words from distractor word sets, varying in levels of similarity from either the categories or idiosyncratic instances encountered during the training phase. Results revealed that adults learned categorical and idiosyncratic word properties; however recognition responses were predominantly based on categorical attributes. On the other hand, children's recognition responses were primarily based on specific instance attributes. The authors concluded that children and adults have the ability to successfully extract specific exemplar information and categorical information, but differ in the proclivity to use categorical information for decision making purposes. Another study by Boswell and Green (1982) explored developmental changes with respect to category representation. Adults and children of ages 4-, 5-, and 6-years utilized the category learning procedure in order to differentiate between sets of geometric figures. Half of the participants were given test instructions stressing the importance of classification accuracy and the other half received instructions to classify old and new items. Findings showed that adults based their classifications on prototype information as opposed to exemplar-specific information. On the contrary, children used exemplar-specific information when classification accuracy was stressed and prototype information when these instructions were not given. Thus, these results may reflect children's dependency on exemplar-specific knowledge when classifying objects.

Interestingly, in a study conducted by Hayes and Taplin (1993) to further investigate developmental differences in the use of prototypical attributes and exemplar-specific information, 6-year-old children used prototype information as a basis of classification, whereas 11-year-olds and adults were relying on exemplar similarity. This finding is consistent with previous research that infants (Quinn, 1987) and young children (Posnansky & Neumann, 1976) possess the ability to abstract prototypes from sets of ill-defined figures. It is worth noting that a large number of participants appeared to have used both prototypical features and specific features of exemplars as a basis for classification, consistent with the mixed model approach (Homa, Sterling & Trepel, 1981).

Another eminent contributory factor involved in category recognition and object classification is inductive reasoning – a process in which children and adults rely on observations to alter confidence in beliefs (Hayes & Heit, 2004). A central characteristic of inductive reasoning models is categorical knowledge. This is applicable for both children (Gelman, 2003) and adults (Osherson, Smith, Wilkie, Lopez & Shafir, 1990). For example, knowing that an object belongs to a familiar category such as a car enables inference of object properties – a car has wheels. Therefore, concluding that other types of vehicles likewise possess this attribute. This generalization of object properties indicates that objects which belong to the same category have common attributes – in line with the central idea of the prototype account.

The next section deals with object locations. According to Treisman (2006), object locations are features of the object themselves which are stored in object files. From this perspective, the cognitive mechanism of object features such as colour or place may not differ. However, one could also assume that locations should exist independently of objects in space. The different types of aggregation and combination of locations are introduced in the following section on array effects in visual memory.

1.6. Array Effects in Place Memory

Young children often lack a projective concept of space. Two Swiss psychologists, Piaget and Inhelder (1956) conducted an experiment to prove this notion. This task involved the diagonal arrangement of figures in a line from point A to point B on a rectangular-shaped table. Children aged 4 years and younger were clustering the figures close to one another, but were unable to evenly position the figures between the two points (Stage 1). Among children who were aged between 4 and 7 years, corners of the table acted as external support to help align the figures but not to create a diagonal which connected points A and B (Stage 2). At 7 years of age, dependency on external support decreased and a successful figure line-up was achieved between the two points (Stage 3). These results were supported by follow-up research validating the concept that the diagonal emerges at a later age (Olson, 1970) and controls the regulation of object size in diagonal spatial axes (Lange-Küttner, 2009).

Piaget (1969) postulated that the formation of a vector necessitates the renunciation of figurative thinking since objects are merely represented as points in mathematical space. Evident in recent research is the reliance and eminence of boundary information for place memory in adults, whereas children were still reliant on landmarks (Bullens et al., 2010). The combination of the two spatial cues, however, undermined performance in adults (Bird, Capponi, King, Doeller & Burgess, 2010). Adults had greater precision when coding angular information, illustrating that they used metric vector information, in comparison to children who used distance between figures when estimating locations. This indicated that children were highly attentive to objects and the spatial relations formed between these objects (Bullens et al., 2010). For the present research, boundary information was used as a visual cue; however its effect was not tested.

Spatial boundaries in an array are visible to the eye, that is, what we see, whereas vectors are mental constructs of spatial axes. A study showed that hippocampal activation was unaffected by the marked increase in visual spatial boundaries, while the mental construction of spatial imagery lead to the predicted hippocampal activation (Bird et al., 2010). Hence, these findings are indicative of a computational role for the hippocampus in the mental construction of spatial imagery.

Research showed that in both animals and humans, including infants and children, information related to array boundaries and landmarks (both of which are spatial cues to aid spatial recall) is stored in long-term memory (Lew, 2011). Among children between the ages of 3 and 4 years, delimiting the search area using explicit spatial boundaries (drawn or rimmed) resulted in heightened performance in a task where re-orientation was required to find an object (Lee & Spelke, 2011). The data generated in the study was performance data compared to the following studies which generated bias data. Firstly, the Categorical Adjustment (CA) model will be considered. According to the model (Huttenlocher, Hedges & Duncan, 1991), two sources of information are used to estimate location, namely fine-grained and categorical information. When children and adults attempt to recall a previously learned location, their estimates are based on memory of fine-grained information, for example, distance and direction from a particular reference location (metric). Nevertheless, these estimates are not always accurate, hence the reason why estimates are adjusted on the basis of categorical information such as region membership. Categorical information is specified by a spatial prototype located at the center of the spatial region. This leads to systematic biases toward the category center in children as they rely on categorical information when uncertainty regarding fine-grained information is high (large biases toward category centers), whereas a low weight is assigned to categorical information when memory for fine-grained information is certain (minute biases toward category centers).

Huttenlocher et al. (1991) used both standard and interference trials when viewing a circle with a dot inside which then disappeared. Participants were required to recall the location of the dot. In the standard trials, participants recalled the location of the dot immediately post removal. Comparatively, in the interference trials recalling the dot location took place after an interference task. The task entailed remembering a visual pattern, lasting between 5 and 8 seconds. During the completion of the interference trials, participants relied on information regarding spatial regions which changed with age. Younger children exhibited greater biases toward category centers, i.e. a prototype, whereas little categorical bias was observed among older children (Huttenlocher, Newcombe & Sandberg, 1994; Hund & Plumert, 2002; Hund, Plumert & Benney, 2002). In another investigation by Huttenlocher and colleagues, these findings were confirmed. Adults were presented with a V frame marked by a line inside. Once the frame and line disappeared, recalling the location of the line was required. However, this differed in the control and interference condition. In the control condition, recall was immediately after, whereas in the interference condition, an interference task intervened with an approximate duration of 8 to 12 seconds (Engebretson & Huttenlocher, 1996). In line with the prediction of the Category-Adjustment (CA) model, estimates of the location were biased toward category centers, with the bias more pronounced in the interference condition compared to the control condition. This is indicative of the fact that individuals rely hugely on categorical information to recall locations, i.e. it is more weighted the more uncertainty regarding fine-grained information (this may be information relating to distance) increases.

Moreover, a study on visuo-spatial memory which used a computerized task revealed that a grid array (explicit spatial boundaries form individual places) facilitated place memory in a subsequent session (*priming*) even when spatial boundaries were not present (Lange-Küttner, 2010b). Therefore, explicit spatial boundaries had a strong facilitating effect on children's location memory. In the current study, a grid array was used during the presentation phase, followed by the presence of an empty grid at test.

1.7. Spatial Development and Learning

A growing body of conclusive evidence has emerged in support of the link between spatial span and age, that is, improvements in spatial memory are directly associated with increases in age (Bayliss, Jarrold, Baddeley, Gunn & Leigh, 2005; Cestari, Lucidi, Pieroni & Rossi-Arnaud, 2007; Cowan, Saults & Morey, 2006; Klingberg, 2006; Riggs, McTaggart, Simpson & Freeman, 2006). In one such study (Cestari et al., 2007), spatial memory development was investigated in three conditions via the employment of a typical span procedure. The conditions included positional reconstruction, object-position binding and a combination of the two in the last condition. These are spatial processes which play a role in short-term place memory, where the exact position in a particular space must be recalled (positional encoding), followed by determining which objects were occupying which positions (object-position binding) (Postma & de Haan, 1996; Schumann-Hengsteler, 1992). The study showed that children's memory increased from 6-, 8- to 10-years across all three conditions. In the current study, memory for one place at a time was tested, that is, in each trial children were required to recall only one location that was occupied by the object (object-in-place). This differentiation may explain why previous object and place memory tasks had longer presentation times, ranging from 1000ms to 5000ms (Lange-Küttner, 2012; 2013; Lange-Küttner & Küttner, 2015), in comparison to the current place memory task with a much shorter presentation time of 750ms.

In a study assessing spatial span and visual memory, two types of displays were presented: concurrent and sequential in a grid with coloured squares (Lecerf & Roulin, 2009). Those adults who did not have a high spatial span had the tendency to recall adjacent places, that is to say, they would remember the place next to the target location especially when the grid was large (i.e. a large number of squares where each square denotes a place). Hence, the study concluded that location memory is of vague nature.

In contrast, Treisman (2006) suggested that place information is held in "object files" which implies that object-place binding is tied to the object itself. Besides place information, objects are described as having multiple features including orientation, size, distance, shape and colour (Bar & Neta, 2007; Mecklinger, Gruenewald, Weiskopf & Doeller, 2004; Kahneman, Treisman & Gibbs, 1992). Accessibility of object files is dependent on spatial location, hence object-to-place binding is pivotal. Although objects have changing appearances, the shape of an object attracts rapid attention and easily becomes unforgettable (Biederman, Yue & Davidoff, 2009). In computerized tasks assessing object place and object shape memory, 5-to 6-year-old children remembered object shapes over places (Lange-

Küttner, 2010a; 2010b). When assessing reaction times, young children were quicker at recalling object shapes versus places (Lange-Küttner, 2010b; 2013), whereas adults were marginally quicker at remembering places than object shapes (Mecklinger & Meinshausen, 1998; Mecklinger & Pfeifer, 1996). Children tend to place greater emphasis on the improvement of object memory, in particular object shape memory as this is a preventative measure against pro-active interference (Lange-Küttner & Küttner, 2015). This interference occurs when memory for previously learned items hampers memory for items presented in a subsequent block (Kail, 2002). An intriguing finding is that in the presence of many objects in a given array, adults focus their attention towards the objects and not places. However, when exposed to multiple places and a decreased number of objects, attention is largely directed towards the places (Logan, 1996; 1998). In the current study, one object was presented in a grid of 25 places, therefore their attention should be fully focused on the places as such.

The selective attention towards objects which are overshadowing of places leads to the question of how attention towards and memory for locations can be improved in children. Harlow (1949) conducted a battery of experiments with monkeys and found that repetition, together with task practice lead to substantial place learning. Lending support to this was the meta-analysis by Uttal and colleagues (2013), collating findings from 188 studies which revealed that practicing a task continuously was the most effective method to enhance spatial learning. This overlaps with the explanation of neural networks, stating that learning is an outcome of repeated exposure (McClelland & Siegler, 2001; McLeod, Plunkett & Rolls, 1998; Siegler, 2000; 2004).

Furthermore, amongst children aged 7-to 9-years, reaction times for object locations accelerated while reaction times increased for object shapes. Repeated viewing of the same object shapes in the same locations resulted in profound place learning (Lange-Küttner &

Küttner, 2015). Therefore, repetition and sameness aided place memory. Spatial concepts were only used when objects and places changed in each block. Thus, it is predicted that the repeated viewing of a stimulus during the delay in the current place memory task will have a powerful facilitation effect on memory formation (see also Bauer, 1997; Druker & Anderson, 2010).

Nevertheless, the effects of repetition are subject to debate. When school-aged children completed repetitive drawing from memory tasks, they often lost specific details (Lange-Küttner, Küttner & Chromekova, 2014). Moreover, in visuo-spatial memory tasks, repeatedly visiting the same location of an object was seen as inefficient processing and perseverative responding (Danziger, Kingstone & Snyder, 1998; Klein, 1988; Posner, Rafal, Choate & Vaughan, 1985). Repetition is often seen as perseveration rather than perseverance (Lange-Küttner & Küttner, 2015). According to the Piagetian developmental psychologists, children do not need several trials, but they assume that the development of the right concept will aid in getting it right the first time. Indeed, with advanced conceptual development, an anti-repetition bias becomes increasingly popular among older children (Witt & Vinter, 2011). Having said that, children who suffer from ADHD often display signs of perseveration (George, Dobler, Nicholls & Manly, 2005; Wilding, 2003; Wilding & Burke, 2006; Wilding, Munir & Cornish, 2001).

In their early years of life, children are able to draw attention away from places they have formerly visited and direct attention toward other places in a given array (Clohessy, Posner, Rothbart & Vecera, 1991). Up until the age of one, infants primarily focus on object shape rather than its location and display perseverative behaviour in relation to the initial place visited. From a developmental perspective, this is referred to as the A-not-B error (Lange-Küttner, 2008). By making individual places more noticeable and attractive, for example through the use of colour, infants' location memory can be facilitated, however these effects are temporary. In a study, the absence of these coloured spatial cues lead to perseverative errors (Butterworth, Jarrett & Hicks, 1982). At the age of 1½ years, infants no longer make these errors since a keenness to discover other places develops (Vecera, Rothbart & Posner, 1991).

Just like children formed an anti-repetition bias, adults developed the inhibition of return (IoR), both of which play an identical role. Consequently, through diminished attention and perseverance, adults become more likely to re-visit locations, commonly attributed to personality differences such as decreased anxiety, impulsiveness and neuroticism (Avila, 1995; Nelson, Early & Haller, 1993) and not age (Castel, Chasteen, Scialfa & Pratt, 2003; Connelly & Hasher, 1993; Hartley & Kieley, 1995). Like infants, adults exhibit reaching biases (Briand, Larrison & Sereno, 2000). In one such study (Howard, Lupianez & Tipper, 1999), the authors found that an interval of 600ms between the cue and target led to robust effects of the IoR in reaction times to initiate the reach. However, effects relating to the movement components were not observed. When there was a short interval of 200ms between the cue and target, hand paths toward the cue were observed. In the current study, children indicated with a reach towards the touch screen where in the places in the grid they had seen the object before.

On the one hand, repeated trials enhance location memory, particularly for the first few locations. On the other hand, perseveration to previously encountered places reduces accuracy of place memory (Dodd & Pratt, 2007; Lange-Küttner, 1998; Marcovitch, Zelazo & Schmuckler, 2002; Munakata, McClelland, Johnson & Siegler, 1997; Spencer, Smith & Thelen, 2001). In a computerized experiment, adults' reaped the benefit of task repetition. The study involved viewing object sets, containing shapes which were either coloured or black and white in appearance. Recognition memory improved in response to seeing one set after the other, as opposed to a single lengthy presentation, despite the fact that the duration of the conditions was equal. The greatest gain in performance was seen among participants with poor visual recognition memory (Ihssen, Linden & Shapiro, 2010). Hence, stimulus repetition may act like a refresher for memory (Camos & Barrouillet, 2011; Logie & Della Sala, 1999) by re-activating the memory traces for the stimulus. In order for this to take place; there is a rapid shift of attention from processing to reactivation. Stimulus repetition also occurs in rehearsal (Jarrold & Tam, 2011), which is the more or less voluntary repetition in one of the working memory sub-systems and requires executive attention. It is clear that there is verbal rehearsal; however, it is unclear how visual rehearsal would work inside the mind. Hence, the current study investigates this question with a delay interference which can be either repetitive or new.

1.8. Delay Effects in Spatial Memory

The ‘location-system’, also referred to as the ‘where-system’ is usually activated in a where-delay task. Nevertheless in the present study, the nature of the delay task was a different what-delay as children had to make a judgement whether the delay object was the same or different to that seen in the presentation phase, so would it hamper or facilitate place memory? Or would the repetition (seeing the same object again in the delay) work to the advantage of children’s memory? Repetition is a mechanism that favours children, whether this is obvious to them or not (Lange-Küttner & Küttner, 2015).

A prime research focus in the field of spatial memory is the effect of delay and its influence on location memory (van der Ham, van Wezel, Oleksiak & Postma, 2007). For example, van der Ham and colleagues showed that when remembering precise locations, the longer the delay the poorer the recall. Delay tasks, also known as interference tasks, are completed prior to the test phase (before location memory is tested) and post the presentation phase (Hund & Plumert, 2002). In one such study (Lange-Küttner, 2013), place learning was investigated in children aged 6-to 9-years and adults, using a reaction-time accuracy task. The experiment entailed a filled delay task, in which a size (small or big) and position delay (either top or bottom) were judged. During the size delay, participants saw animals such as elephants, ants and rhinoceros. In reality, these animals vary in size, but in the experiment a standard size was allocated. When a large animal appeared on the screen, for example an elephant, children were required to respond with the push of a button. The position delay comprised of birds on the screen flying, either at the top or bottom and children were expected to respond when the bird was flying on top. The size delay predicted object shape memory, whereas the position delay predicted place memory. Results revealed that slow reaction times in adults when completing the position delay task lead to superior place recognition in the test phase. Hence, this may imply that adults were keeping an eye on reaction times. One could reason that a lengthy delay is linked to poor memory since children have constrained cognitive capacity. Nevertheless, recognition memory of 6-to 7-year-olds benefitted from a longer delay as it may allow for the better organisation of memory material (Lange-Küttner, 2012).

In another variation of the object and place memory experiment, which adopted the what and where methodology (Lange-Küttner & Küttner, 2015), the what-delay impacted how accurately children responded. When they took longer to decide whether an animal was big or small, memory accuracy improved. This again revealed the importance of objects in children (Jolley, 2008). In addition, those children who performed faster in the where-delay task had faster reaction times in the place test. Thus, the what-delay task held significance for memory accuracy, whereas the where-delay task was important for reaction times.

1.9. The Present Study

In the context of the present study, spatial memory in children was investigated using a microgenetic analysis approach (Siegler, 2000). A repeated measurement experimental design comprising of several blocks with shapes of different object categories and their places in the grid tested location memory. During each trial, one object occupied one place which did not change during the test trial. Children were instructed only to remember the places and not the objects per se. There were no distracters as children just touched the screen to indicate the object's place in a grid with 25 places. This repeated measurement was used in a mixed factorial design with a group factor comprising children with ASD vs. ADHD as well as the groups of age-matched and IQ-matched controls.

During the place memory experiment, children completed a delay task prior to the location memory test and post the object-in-place presentation. The nature of the delay was a what-interference task: Children either saw the same-object (same-object delay), identical to that seen in the presentation phase or a different-object delay which was an exemplar of the same object category.

The study tested two clinical populations: children with ASD and children with ADHD. A large body of research has suggested that among ASD children significant impairments in spatial working memory (WM) are noted. In a meta-analysis conducted by Wang and colleagues (2017) which included a total of 29 studies comparing 862 individuals with ASD and 899 healthy controls, found that spatial working memory was more impaired than verbal working memory. This was represented by a comparison of effect size between spatial (d = -0.72) and verbal (d = -0.49) working memory. Parallel findings were revealed by another meta-analysis of 24 studies evaluating various measures of working memory (Kercood, Grskovic, Banda & Begeske, 2014). Results suggested that individuals with ASD exhibit lower scores than healthy controls on tasks that require spatial working memory, cognitive flexibility and greater WM load to name a few. Furthermore, a similar pattern of results were reported by Williams and colleagues (Williams, Goldstein, Carpenter & Minshew, 2005; Williams, Goldstein & Minshew, 2005; 2006). For example, Williams et al (2006) administered a clinical memory test to a sample of 38 high-functioning ASD children and 38 matched neurotypicals between the ages of 8-to 16 years. Among children with ASD (versus matched controls) significant deficits were found in spatial working memory, together with impoverished memory for complex verbal and visual information. However, verbal working memory, recognition memory and associative learning ability were intact. Further analysis showed that the Finger Windows subtest, used to measure spatial working memory, was the most accurate at comparing performances of ASD children and neurotypicals. It is worth noting that the visuo-spatial working memory tasks used to assess spatial memory in the studies discussed are in the majority multiple object procedures, for example, the block recall task and visual patterns task, thus spatial memory needs the support of executive attentional resources in order to complete such tasks. These resources are challenged in children with ASD (Hill, 2004; Rajendran & Mitchell, 2007), hence contribute to poor performance. The evidence, however, is inconsistent. In a study by Ozonoff and Strayer (2001), individuals with autism and control participants completed a spatial memory-span task and a box search task. During the computerized spatial memory-span task, participants were required to recall the location of three to five geometric shapes. The box search task entailed searching for objects hidden behind coloured boxes. This required the retention of the box colour in working memory during search. When performances of the ASD children and control participants were compared on these two tasks, no significant differences were noted. This shows that among individuals with ASD, spatial memory was relatively intact.

Furthermore, other authors have reasoned that the effect of cognitive load is behind the spatial working memory deficit in autism (Goldberg et al, 2005; Williams, Goldstein & Minshew, 2006; Steele, Minshew, Luna & Sweeney, 2007). In one such study, Steele and colleagues (2007) demonstrated that among ASD individuals performance on the spatial working memory task became impaired as set size increased, that is, with increments in cognitive load. Nevertheless, one can infer that in the current study children were asked to remember the location of only one object-in-place at a given time, thus 1) decreased demand on executive attentional resources 2) low cognitive load and 3) attention to detail in ASD individuals may all contribute to heightened performance on the location memory task.

In a quest to explore visuo-spatial performance in ADHD children, Westerberg and colleagues (2004) administered a computerized visuo-spatial working memory task in which children were presented with circles one at a time in a four by four grid. The task was to remember the locations occupied by these circles and responses were made only after all the circles in each trial were presented. Increments in working memory load ranged from two to nine circles. Results of the study provided support for the hypothesis that children with ADHD exhibit impairments in visuo-spatial memory, particularly spatial memory (Westerberg, Hirvikoski, Forssberg & Klingberg, 2004). Another study investigated spatial memory ability in 7-to 12-year-old boys with ADHD versus age matched healthy controls. All children completed a laboratory-based object location learning task, whilst also being videotaped by the experimenter. The findings demonstrated that boys with ADHD showed a deficit while learning object locations, that is, spatial memory was impaired (Reck, Hund & Landau, 2010). In the ADHD research discussed, spatial pathway Corsi-like tasks (Della Sala, Gray, Baddeley, Allamano & Wilson, 1999) and Silverman & Eals procedures (Silverman & Eals, 1992) were used, which are high in executive attention resource demand. For example, the study by Reck and colleagues (2010) tests location memory of multiple (20) object items in an array using the Silverman & Eals location memory task, thus overloading the memory system, which would typically require attentional resources to support performance. Just like ASD children, individuals with ADHD also have challenged attentional resources (Rapport, Friedman, Eckrich & Calub, 2018) undermining their performance on such tasks. This contrasts with the spatial memory protocol of the current study, where a single item location binding is required and spatial memory for each place can be directly assessed. However, in order to focus on a single location of many (25 places in the grid), visual attention needs to be narrowed, which may pose a difficulty for children with ADHD since they are less likely to confine their visual attention (Shalev & Tsal, 2003). This may potentially lead to performance impairment.

Following on from this discussion, three main hypotheses were under investigation. The primary hypothesis refers to location memory of the clinical and control groups. In a predicted effect of group, autistic children compared to ADHD children and respective controls were expected to show good or premature location memory. On the other hand, children with ADHD (versus matched controls) may demonstrate impairments in location memory and more response perseveration.

The second hypothesis explored intense and circumscribed interests found commonly in typically developing children (DeLoache, Simcock & Macari, 2007), as well as those suffering from neurological conditions such as ASD (Lord, Rutter & Le Couteur, 1994; Baron-Cohen & Wheelwright, 1999). In a predicted effect of content, location memory would benefit more from the technical objects, in comparison to the roleplay and neutral objects. That is to say, memory performance when locating the technical objects such as vehicles and construction sets would be the highest. Over the past years, a large framework of evidence has emerged (see section 1.3) in support of these preferences and interests, stating that children become fascinated by particular objects or categories of objects. These interests are gender-specific, however prevail especially in males than in females (Baron-Cohen, 2002). The majority of children tested in the current study were males, hence the choice of object categories such as vehicles, lego and construction sets. One can infer that categories such as dolls and cuddly toys acted as control categories because these were more common interests found in girls. This study will also aim to extend current research within this domain by the inclusion of ADHD children, since previous research has primarily focused on neurotypicals and children with autism. Taking into consideration the research evidence discussed above, a potential interaction effect between group and object factors was predicted.

The final hypothesis concerned the delay task, which was presented between the presentation and test phase. The interference paradigm, also known as filled delay tasks were used in previous visuo-spatial memory studies (Engebretson & Huttenlocher, 1996; Huttenlocher, Hedges & Duncan, 1991; Logie & Marchetti, 1991; Lange-Küttner & Friederici, 2000; Lange-Küttner, 2010a; 2013; Lange-Küttner & Küttner, 2015). In a predicted effect of delay, same-object delay versus a different-object exemplar would facilitate place memory and this facilitation effect would apply to the technical, roleplay and neutral objects, giving rise to a potential interaction between the delay and object factors. Extensive research supports the concept of repetition in spatial memory, whether that is related to stimuli repetition or repetition of the task itself (Bauer, 1997; Harlow, 1949; Uttal et al., 2013). The same object is consistently and repeatedly shown but the different object is predicted to hamper children's place memory, acting as a distractor. In particular, this may be the case for ADHD children considering the documented ADHD-related weaknesses in interference control (Mullane, Corkum, Klein & McLaughlin, 2009), alongside the evidence for ADHD-related impairments in category learning tasks (Romine et al., 2004; Huang-Pollock, Maddox & Tam, 2014). Conversely, one could also infer that the different-object exemplar may not be a true distractor for ASD children and neurotypicals considering their ability to recognise and classify instances of a given category (see section 1.5). This would lead to a potential interaction effect between the delay and group.

Furthermore, research studies have shown that spatial binding strategies are a predictor for spatial memory (Lange-Küttner, 2010a; 2010b; 2013), which in the current study is assessed via the Common Region Test (CRT). In fact, ASD and ADHD are both mental health disorders where a common underlying problem in spatial binding may result in a high number of unsystematic coders in these clinical samples. Therefore, a potential effect of the CRT is predicted, together with an interaction effect between the coding group and experimental group.

Although particular array effects were not tested in this study, the type of spatial array does have an influence on place memory. In the presentation phase of the experiment, a grid was shown in which an object occupied a place in each trial. A grid consists of explicit boundaries delimiting individual places, hence is considered as a powerful and supportive array. Furthermore, it is known to aid categorical spatial information and relations (Kosslyn, 1996; Kosslyn, Flynn, Amsterdam & Wang, 1990; Postma, Kessels & Van Asselen, 2004; Schneider, Gruber, Gold & Opwis, 1993). In the test phase, an empty grid appeared and children were required to recall the location of the object. Thus, the grid array was chosen in the hope that it will benefit place memory to some extent.

2. METHOD

2.1. Design. Accuracy and reaction times of place memory were analysed in a 2 (same-object vs. different-object delay) by 3 (object type: technical vs. roleplay vs. neutral) by 6 (experimental groups: ASD, ADHD, ASD MA, ASD CA, ADHD MA, ADHD CA controls) MANOVA, with repeated measures on the first and second factor. In the analyses thereafter, the same model was controlled for verbal mental age (VMA), Raven, age (in months) and the Bender Gestalt score as covariates. Multiple comparisons of the group factor were carried out within the model. If the Mauchley's Test of Sphericity reached significance, degrees of freedom were adjusted according to Huynh-Feldt. Interactions with covariates are followed up with correlations.

2.2. Participants. The sample of N = 117 school children from various schools in South-West London, UK, took part in the study, mainly White English (55.8%) and Asian (36.7%) children. Children from other ethnicities in this area of London were Black English

(4.2%) and Other White (3.3%). The special needs schools included: Strathmore, Lindon Bennett and Grey Court. Mainstream schools were as follows: Teddington, Waldegrave, Stanley Primary, Christ's, Hampton, Hounslow Town Primary, Heston Community and Primary, Twickenham Academy, Orleans Park, Heathland, Matthew Arnold, St. Paul's Catholic College, Stanwell Fields Primary, Wellington Primary and Guildford. The formal diagnosis of ASD and ADHD was made by the respective special schools, which then guided sampling for the present research.

Children with ASD and ADHD completed both of the diagnostic measures in order, first, to confirm the diagnosis of the school and, second, to rule out the possibility of co-morbidity. Thus, children with ASD and ADHD were required to meet specific inclusion and exclusion criteria. The inclusion criterion for children with ASD was a score of above 30 in the Childhood Autism Rating Scale CARS 2 (Schopler, Van Bourgondien, Wellman & Love, 2011), non-autistic scores are 15-30 (see also Grice et al., 2005). The inclusion criterion for children with ADHD was the 80th percentile as a cut-off point of the DuPaul ADHD Rating Scale (DuPaul, Power, Anastopoulos & Reid, 1998). The CARS 2 and DuPaul ADHD Rating Scale scores for the two clinical groups are as follows. *ASD Group.* CARS 2: M = 36.0, SD = 1.9, Range = 33.5 to 40.9. ADHD Rating Scale (percentile score): M = 14.0, SD = 6.7, Range = 10.0 to 25.0. *ADHD Group.* ADHD Rating Scale (percentile score): M = 94.3, SD = 5.2, Range = 80.0 to 99.0. CARS 2: M = 19.2, SD = 1.7, Range = 16.5 to 27.0. Another inclusion criterion for children with ASD and ADHD was their suitability to participate in the study according to the Mental Capacity Act (2005). The child was included in the study if they were believed to have mental capacity to consent and to carry out the task.

The exclusion criteria for all children were as follows: 1) Children with a mental age below 6 years were excluded from the study and 2) Children not in command of the English language were not tested because although the task was non-verbal in nature, rudimentary communication between the child and experimenter was necessary for consent and task instructions. In the following text, for the ease of reading, the group of children who are in the autistic spectrum are abbreviated as ASD children or ASD group, and likewise for the hyperactive children with attention deficits the mention is abbreviated to ADHD children or ADHD group.

The typically developing (TD) children did not have a known psychiatric diagnosis and were matched one-to-one with the children in the clinical groups on measures of chronological age (CA) (see Table 1), mental age (MA) by verbal intelligence as this is the domain where ASD children are the most disadvantaged bedsides pragmatic skills (see Table 2) and gender.

Two data sets of the control groups were excluded from the analyses due to a technical error/missing data. Another data set was excluded due to an extremely low VMA of 30 months, hence was considered as an outlier in comparison to the rest of the VMA scores. Of the remaining, N = 117, the ASD group consisted of n = 19, 17 boys, 2 girls (range 7;0 to 15;3) (years; months). The ADHD group consisted of n = 20, 15 boys, 5 girls (range 8;9 to 16;4). The ASD MA (mental age) control group consisted of n = 19, 17 boys, 2 girls (range 7;5 to 15;0) and the ASD CA (chronological age) control group consisted of n = 19, 17 boys, 2 girls (range 7;0 to 15;3). The ADHD MA control group comprised of n = 20, 15 boys, 5 girls (range 9;4 to 16;10) and the ADHD CA control group comprised of n = 20, 15 boys, 5 girls (range 8;9 to 16;4).

Table 1
Special Needs and Control Groups' Mean Age

Special Needs Groups	Age in Months	Control Groups	Age in Months	p-value
ASD (n=19)	116	ASD MA Control (n=19)	130	.000
ASD (n=19)	116	ASD CA Control (n=19)	116	1.00
ADHD (n=20)	160	ADHD MA Control (n=20)	164	1.00
ADHD (n=20)	160	ADHD CA Control (n=20)	160	1.00
N=39		N=78		Total N=117

Note. MA = mental age, CA = chronological age.

Table 1 shows that on average, children in the ADHD groups were older than children in the ASD groups. This age difference between the two clinical groups occurs because the clinical diagnosis of autism takes place at a much earlier age than ADHD, which is diagnosed later in a child's life. Table 1 also shows that the MA control group for the ADHD children is of the same age (Schuck & Crinella, 2005), while the MA control group for the ASD children is older. This would suggest that the children with ASD had above average IQ than expected by their chronological age.

Table 2
Special Needs and Control Groups' Mean Intelligence Scores

Special Needs Groups	Scores	Control Groups	Scores	p-value
ASD (n=19)	BPVS = 123 RCPM = 23 Bender = 9	ASD MA Control (n=19)	BPVS = 123 RCPM = 29 Bender = 15	1.00 .000 .000
ASD (n=19)	BPVS = 123 RCPM = 23 Bender = 9	ASD CA Control (n=19)	BPVS = 119 RCPM = 30 Bender = 15	.633 .000 .000
ADHD (n=20)	BPVS = 162 RCPM = 28 Bender = 15	ADHD MA Control (n=20)	BPVS = 162 RCPM = 30 Bender = 17	1.00 .116 .052
ADHD (n=20)	BPVS = 162 RCPM = 28 Bender = 15	ADHD CA Control (n=20)	BPVS = 159 RCPM = 33 Bender = 18	1.00 .000 .001
N=39		N=78		Total N=117

Note. BPVS= British Picture Vocabulary Scale, RCPM = Raven Coloured Progressive Matrices, Bender = Bender Gestalt Test II

Table 2 shows that the two groups of children with special needs were matched on vocabulary. However, all control groups had better scores on the non-verbal measures, and most independent samples t-tests were highly significant with the exception of the ADHD MA control group where the difference was not quite as large.

2.3. Apparatus and Material. All children completed the **Common Region Test (CRT)**, which was used to predict spatial memory. This comprised of a sheet of paper, with three rows of dots: row A, B and C. Row A consisted of equidistant dots (filled black), row B were pairs of dots that were closer together than the other pairs of dots (filled black, proximity) and row C were equidistant but pairwise coloured dots (black/white, similarity) (Lange-Küttner, 2006). Children were given the following instruction: “Please draw a circle around those dots which you think belong together”. Scoring of the CRT was based on whether children had drawn a circle around individual dots (object-place binding), matching dots (object-area binding) or whether there was a combination of approaches (unsystematic coding). Inter-rater reliability for all 117 drawings was 99.1%. The one disagreement was settled in a discussion.

The **Bender Visual Motor Gestalt (II)** test (Brannigan, 2003) was used to evaluate visual-motor integration skills, comprising of four sub-tests. These Bender tests consist of a number of figures which children process in different ways.

The ***Bender Motor Test*** included one sample item and 12 figures (four test items with three figures per item). Children were instructed to ‘Draw a line connecting the dots without touching the borders’. For each correct item, one point was allocated and for each incorrect item, a score of zero points was given. A raw score was obtained by summing the correct responses.

For the ***Bender Perception Test***, children were asked to 'select the design that best matched the design in the left column' (ten designs). The scoring and raw score calculation was identical to that of the Motor Test.

During the ***Bender Copy Test***, children were presented with picture cards one at a time. The instruction given was: 'Copy each drawing onto the sheet of paper'. Each design was scored in accordance to the Global Scoring System, where a score of 0 indicated no resemblance, 1 = slight-vague resemblance, 2 = some-moderate resemblance, 3 = strong-close resemblance and 4 = perfect. A raw score was calculated by adding the individual scores.

The ***Bender Recall Test*** was administered immediately thereafter. Children were instructed: 'Draw as many of the designs that you can remember'. Likewise, this was scored using the Global Scoring System and the raw score was obtained accordingly. For all four sub-tests age-based standardized scores were attained.

In order to ascertain mental age, the **British Picture Vocabulary Scale (BPVS)** (Dunn, Wheiton & Pintilie, 1982) was used. This consisted of six training plates and 32 item plates (each plate has four pictures). Children were presented with one plate at a time and instructed to point at the picture corresponding to the test word said by the examiner, for example: 'Please tell me which picture best shows the word bucket'. The score was calculated as described in the test manual.

The **Raven's Coloured Progressive Matrices (RCPM)** test (Raven, 1998) was used to measure non-verbal IQ. This test consisted of 36 item plates, split into three sets of 12 item plates each. One plate at a time was presented and children were required to point at the pattern (out of six choices) that best-fit the puzzle, with the instruction: 'Point to the missing piece that best fits the puzzle'. A raw score was tabulated by adding the number of correct responses per set to obtain a grand total (CPM score).

Both the BPVS and RCPM raw scores were then transformed into age-based standardized scores using published norms.

Diagnostic measures. In the special schools, the diagnostic session entailed the completion of the Childhood Autism Rating Scale (CARS2) (Schopler, Van Bourgondien, Wellman & Love, 2011) and the ADHD Rating Scale-IV (DuPaul, Power, Anastopoulos & Reid, 1998), determining the intensity of the symptoms. Teachers and parents of the clinical groups completed both of the scales.

The **CARS2-ST** (filled out by teachers) included 15 items, relating to the crucial areas of the autism diagnosis, such as emotional and visual response, verbal communication, object and body use to name a few. Teachers were asked to rate the child on a scale from 1 to 4.

The **ADHD Rating Scale-IV** (home version completed by parents and school version by teachers) included two symptom subscales: Hyperactivity-Impulsivity and Inattention with nine items each. The items were rated on a 4-point scale (0 = never/rarely, 1 = sometimes, 2 = often, 3 = very often). Both rating scales were administered according to the standardized testing procedures. Age-based standard scores were obtained for the CARS2-ST and the ADHD Rating Scale.

The ***place memory task*** was developed using the experimental programming software Eprime. In each experimental block, the item sequences in the presentation and test trials were randomized. The experiment was written and controlled on a 14-in. Toshiba Tecra M10 laptop (Intel Core Duo 2.53GHZ, 3GB memory) running Windows 7. The experiment was designed as a touch screen display geared towards young children.

The experimental sequence is presented in Fig. 2. In summary, each experimental block comprised of the presentation of an object-in-place, i.e. an object appeared and disappeared in a place on the grid. Following the presentation of the delay object in the interference task, participants were given a place memory test in which they were required to touch the target location seen in the presentation phase of the experiment. During the presentation trials, children would see an object in a 5×5 grid comprising of 25 places, with a chance level of 4%. Each object appeared on the screen for duration of 750ms. This was a shorter presentation time when compared to other studies with children (Lange-Küttner, 2012; 2013) because only one object in one place was presented per trial, rather than a series of objects in different places. The time for the response was unlimited. Timing of the presentation, delay and test is detailed in Fig. 2.

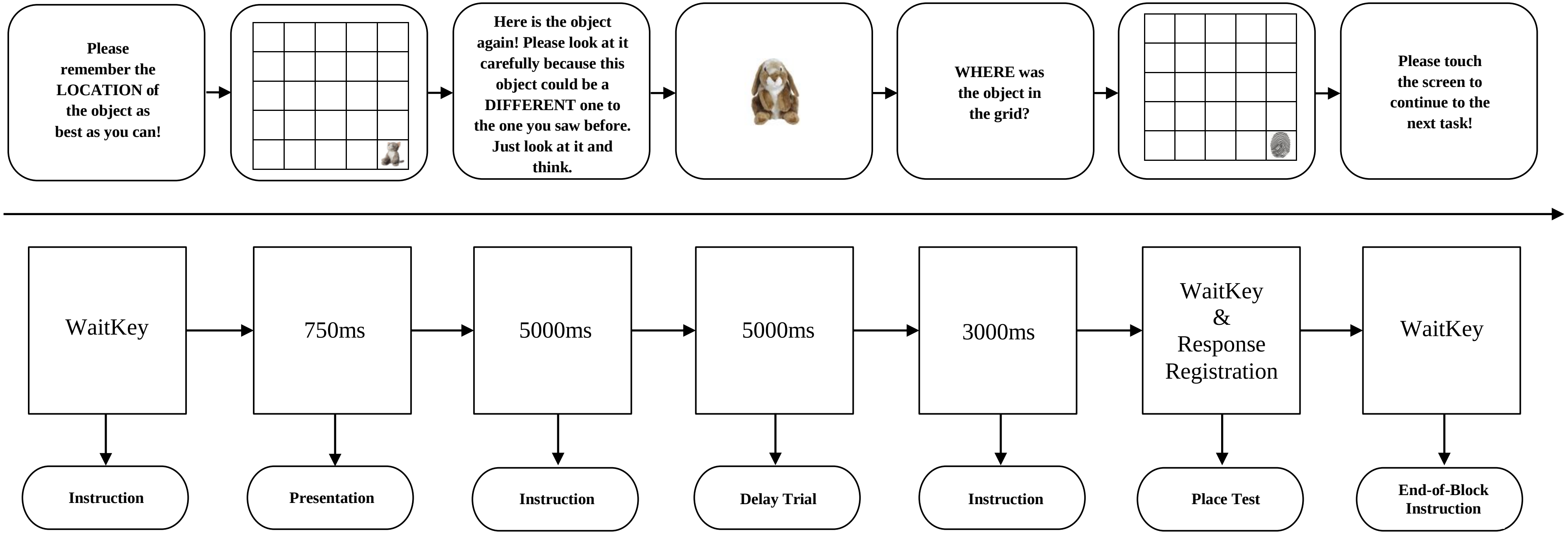


Figure* 2 *The Experimental Timeline. The first row represents the components of one block in the place memory test, with an object delay. Both the delay and test items were presented in a randomized sequence. The grid presented in the place memory test was an empty grid, with a fingerprint icon used to demonstrate a touch-screen display. The second row details the timing in milliseconds for individual components within a block. The stimuli represented in this timeline are mere illustrations and do not commensurate to the exact size used in the experiment (please refer to the text for details).

The target items and distractors were presented in a completely randomized sequence throughout the experiment, executed by the experimental program. In the experiment, a grid with 25 places was presented, where in each trial an object appeared. This was followed by a screen with an object that was either the same or different (delay) on four trials each. Interference objects were exemplars of the same category. The response released immediate feedback, where the rim of the place turned red indicating an incorrect response or green which was indicative of a correct response before the next trial commenced.

Images of the objects in the delay task were 65mm×40mm (height × width) and those images seen in the presentation phase were 50mm×30mm. The delay objects and target images were not a standardized size because the delay task was an empty expanse and not a grid, whereas in the presentation phase, the grid (made up of smaller regions) restricted the size of the object picture.

Objects used in the memory sets were real-life objects from the Bank of Standardised Stimuli (BOSS). This picture set has been normalized for picture complexity, name agreement, familiarity and category (Brodeur, Dionne-Dostie, Montreuil & Lepage, 2010). Object pictures were also captured from various online toy shops. These were categorically defined into ten categories as follows: construction metal sets, construction plastic sets, dolls, vehicles, lego, musical instruments, sports items, school items, playmobil and cuddly toys (see Appendix A). Each category consisted of 8 items, yielding a total of 80 items (8×10 = 80). In previous studies, geometrical shapes were used (Lange-Küttner & Küttner, 2015; Lange-Küttner, 2010a; 2010b; 2013; Mecklinger & Muller, 1996), so this is an important extension of previous research.

2.4. Procedure. Children were tested in classrooms of the schools, which were not used during this time. Consent was obtained individually from parents and children (see Appendix B). The testing session was distributed across a two-day period. Depending upon the school diagnosis, teachers were required to complete the relevant diagnostic rating scales. Children began the session with the CRT, followed by the Bender-Gestalt (II), BPVS and the RCPM tasks. Progression onto the second day of testing entailed the place memory task. Upon completion of the task, children were given a sticker as a reward for participation. The approximate duration of the experiment was 30 min, including welcome and introduction. The computerized instructions were read aloud by the experimenter throughout the task. The introductory text read: ‘Welcome to this place memory experiment!’ ‘Please touch the screen to continue...’ The instructions presented during the experiment were as follows: *Presentation*: ‘An object will appear in a grid on the next screen’ ‘Please try to remember exactly where the object was’ ‘Please touch the screen to continue...’ (object appeared in grid and disappeared). *Delay task*: ‘Here is the object again!’ ‘Please look at it carefully because this object could be a different one to the one you saw before’ ‘Just look at it and think’ (object appeared in the center of the screen and disappeared. The object did not appear in a grid). The instructions in the *place test* read: ‘Where was the object in the grid?’ ‘Touch the screen at the exact location’ (empty grid appeared. The rim of the place touched by the child either turned red, indicating an incorrect response or green if the correct location was selected). Each trial consisted of the same presentation and test instructions. The concluding text read: ‘Thank you for taking part!’.

2.5. Data Generation. In the delay task, children were instructed to just look at the object and no response was required. The duration of the delay was standardized for all the participants (see Fig. 2 for timing details), therefore delay duration per participant, which has previously been computed in other studies did not need to be calculated (Lange-Küttner, 2012; Lange-Küttner & Küttner, 2015).

Each participant completed a total of 80 test trials. There were 10 object categories, each containing 8 objects, so 8×10 = 80. A mean score for the number of correct responses (location hits) per object category was calculated for accuracy (in %) using SPSS (see Appendix C). In half of the delay trials, the same object as seen in the presentation phase was presented, while in the other half a new category exemplar was shown. Hence, for each object category, percentages were calculated separately for same-object and different-object trials. A z-transformation was excluded, so that percentages mirrored the actual performance of children (Shaw, 1984). Reaction times were calculated only for successful responses.

In order to increase the effect of the object type, the 10 toy categories were aggregated into three main categories: technical (construction metal sets, construction plastic sets, lego and vehicles), roleplay (playmobil, cuddly toys and dolls) and neutral (musical instruments, sports items and school items). The ratio of the items in the aggregated object type categories was 32:24:24 resp. technical: roleplay: neutral.

3. RESULTS

In the following sections, the results of the analyses of variance of accuracy and reaction times of place memory are reported. At first, a mixed MANOVA with repeated measures for the two within-subject factors Object Categories and Delay and the between-subject factor Group (TD/ASD/ADHD) was run. Thereafter, the same model was controlled for age (in months), verbal intelligence (VMA), visual intelligence (Raven) and the Bender Gestalt (visual-motor integration skills). Multiple comparisons of the group factor were carried out within the model. Moreover, post-hoc tests (Scheffe) of the within-subject factors are reported if they had more than two levels and were significant. If the Mauchley's Test of Sphericity reached significance, degrees of freedom were adjusted according to Huynh-Feldt. Statistical effects are shown in relevant tables and the statistical values in the tables are not cited again in the text. Interactions with covariates are followed up with correlations. The exact value of the p-level is reported; p-levels smaller than .000 are reported as < .001.

3.1. Accuracy Analysis

Results of the analysis of place memory accuracy scores with a 2 (same-object vs. different-object delay) by 3 (object type: technical vs. roleplay vs. neutral) by 6 (experimental groups) MANOVA are shown in Table 3.

Table 3
MANOVA effects of place memory accuracy (*N*=117)

Statistical Effect	df	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**131.37**	**.000**	**.538**
Object type*Group	10	.466	.911	.020
Delay	**1**	**164.59**	**.000**	**.593**
Delay*Group	**5**	**5.38**	**.000**	**.192**
Object type*Delay	**2**	**3.30**	**.039**	**.028**
Object type*Delay*Group	10	1.34	.210	.056
Between-subject Effects				
Group	**5**	**10.03**	**.000**	**.307**

Note. Significant effects are set in bold

The multiple comparisons of the main group effect showed a significant difference in memory performance between the ASD group and ASD MA controls ($p < .001$), with ASD children showing significantly better memory (M = 64.9%) than the MA controls (M = 52.3%) (see Table 4 and Fig. 3).

Table 4
Accuracy Mean Scores (Group main effect)

	Children with ASD		
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	64.9	52.3***	68.4
	Children with ADHD		
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	63.5	59.3	67.3

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p <$ .05 = *, p < .01 = **, p < .001 = ***

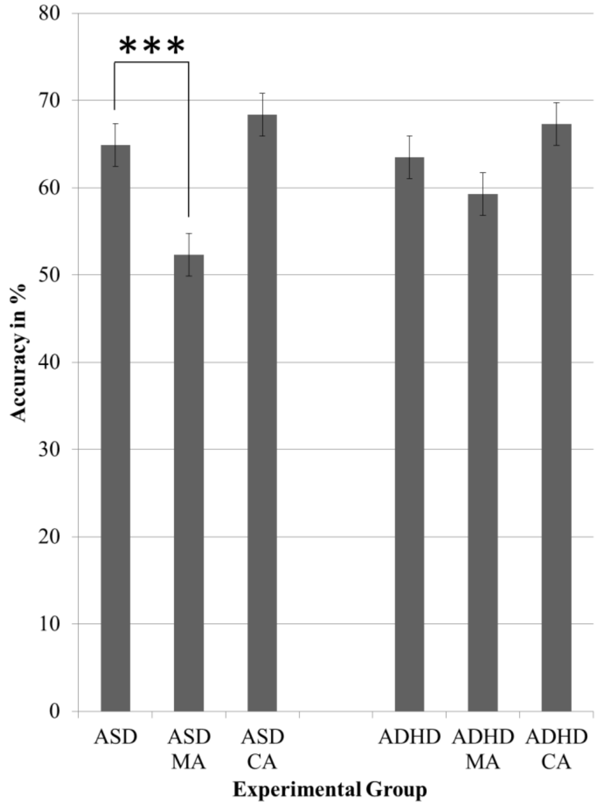


Figure* 3. *Accuracy. Main effect of experimental group on accuracy mean scores. *** = $p <$ .001 (stars indicate differences in accuracy). Means with standard error (SE) bars.

This finding clearly showed that autistic children had better location memory than would have been predicted by their mental age. There was no difference between ASD and ASD CA controls ($p > .05$). No significant differences were found between the ADHD group and the respective controls ($p_s > .05$).

Also the type of object presented (content) was significant, see Table 3, but this was independent of group. This was a highly significant effect showing that place memory accuracy was the highest for technical objects (M = 80.4%), in comparison to roleplay (M = 60.1%) and neutral objects (M = 61.2%), showing little difference in memory performance. Post-hoc pairwise comparisons within the model revealed that the technical objects differed significantly from the roleplay ($p < .001$) and neutral ($p < .001$) object categories (see Fig. 4). This finding showed the main attraction of technical toys for this mostly male sample.

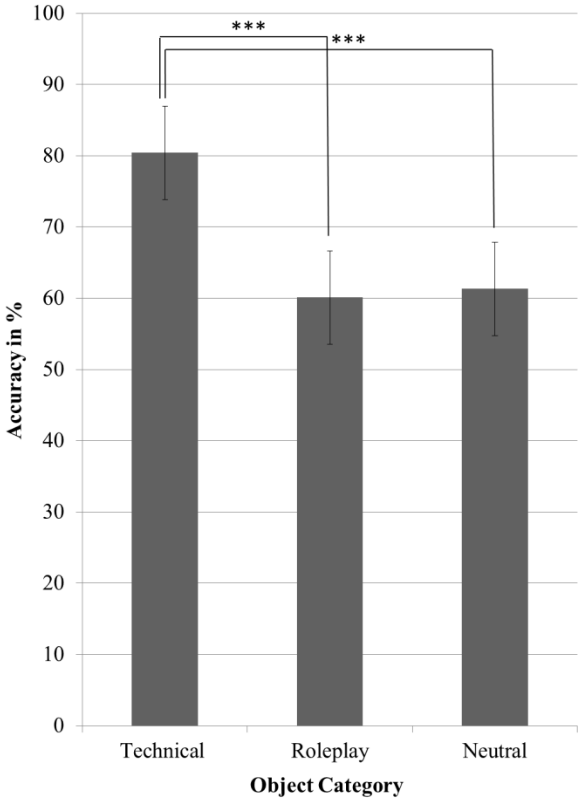


Figure* 4. *Accuracy. The effect of content on place memory performance. *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

The delay effect (same-object delay versus different-object exemplar) was also significant (see Table 3). When the same object was presented again in the filled delay task, place memory was significantly better (M = 69.9%), than if another object exemplar was presented (M = 55.4%), ($p < .001$, see Fig. 5). Hence, viewing the object again in the delay task facilitated children's place memory.

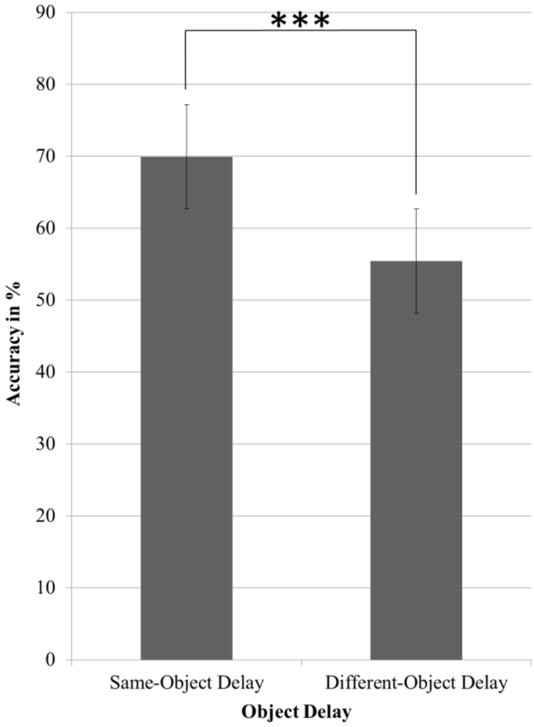


Figure* 5. *Accuracy. The effect of delay on place memory performance. *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

The two-way interaction between delay and experimental group was highly significant. All groups significantly benefitted from the same-object delay, in comparison to a different-object exemplar benefit, but the difference was smaller in the ASD group, see Table 5 and Fig. 6.

Table 5

Delay Effect (Same-Object versus Different-Object Delay) on the Accuracy Mean Scores of the ASD, ADHD and Control Groups

	Children with ASD		
Delay	ASD clinical	ASD MA controls	ASD CA controls
Same-Object Delay	67.8**	61.8***	76.5***
Different-Object Delay	62.0	42.8	60.4
	Children with ADHD		
	ADHD clinical	ADHD MA controls	ADHD CA controls
Same-Object Delay	69.8***	70.0***	73.3**
Different-Object Delay	57.3	48.5	61.4

Note. T- tests are pairwise comparisons of the same-object against different-object delay per group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

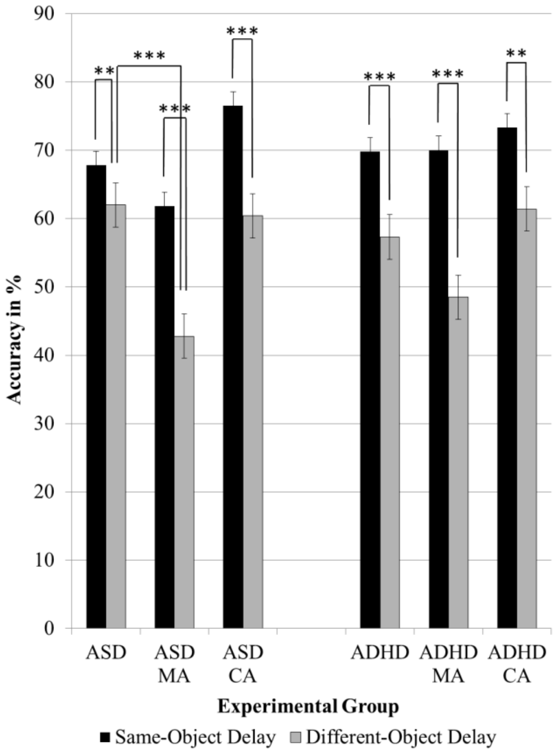


Figure* 6. *Accuracy. The effect of delay on place memory performance of the clinical and control groups. *** = p < .001, ** = p < .01 (stars indicate differences in accuracy). Means with standard error (SE) bars.

Post-hoc tests for independent samples revealed a highly significant difference in place memory accuracy between the ASD group (M = 62.0%) and ASD MA controls (M = 42.8%) when the target and delay stimuli differed from one another $t(38) = 6.16$, $p < .001$.

Additionally, the two-way interaction of object type by delay was significant. Memory performance in all three object categories benefitted from seeing the same-object delay versus different-object exemplar in the filled delay task (see Table 6).

Table 6

Delay Effect (Same-Object versus Different-Object Delay) on the Accuracy Mean Scores of the Three Object Categories

	Object Category		
Delay	Technical	Roleplay	Neutral
Same-Object Delay	89.1***	66.2***	70.2***
Different-Object Delay	71.7	54.1	52.3

Note. T- tests are pairwise comparisons of the same-object against different-object delay, per object category. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

Post-hoc t-tests (two-tailed) revealed that comparisons of the same against different-object delay were significantly different for the technical objects $t(116) = 8.35$, $p < .001$, roleplay objects $t(116) = 5.98$, $p < .001$ and neutral objects $t(116) = 9.67$, $p < .001$ (see Fig. 7).

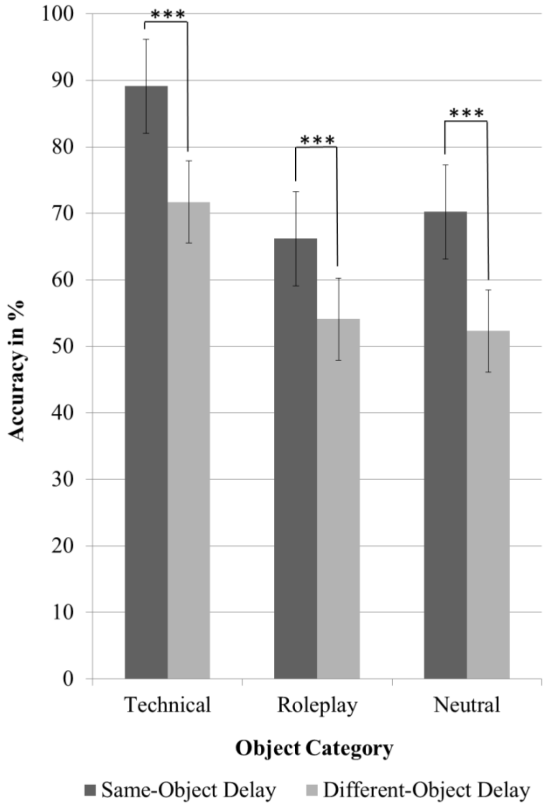


Figure* 7. *Accuracy. The effect of delay on place memory performance of the technical, roleplay and neutral object categories. *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

Due to the fact that significant age differences were revealed between the older ADHD and younger ASD groups (see Table 1), the accuracy analysis was run again with age (in months) as a covariate. Age had no direct impact on the results, see Table 7, but several effects disappeared. The effect of content was still significant, but the content by delay effect was no longer significant showing that this effect was caused by age differences.

Table 7
MANOVA effects of place memory accuracy, controlled for age in month (*N*=117)

Statistical Effect	*df*	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**14.94**	**.000**	**.118**
Object type*Age	2	2.71	.069	.024
Object type*Group	10	.544	.857	.024
Delay	1	2.52	.115	.022
Delay*Age	1	.869	.353	.008
Delay*Group	**5**	**5.10**	**.000**	**.186**
Object type*Delay	2	.053	.948	.000
Object type*Delay*Age	2	.301	.740	.003
Object type*Delay*Group	10	1.32	.219	.056
Between-subject Effects				
Group	**5**	**10.35**	**.000**	**.316**
Age	1	1.73	.192	.015

Note. Significant effects are set in bold.

A main effect for experimental group emerged again as in the prior analysis in which age was not controlled (see Table 8 and Fig. 8), with the ASD group performing significantly better than the ASD mental age controls, $p < .001$.

Table 8
Accuracy Mean Scores (Group main effect) controlled for age in month

Children with ASD			
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	65.8	52.7***	69.4
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	62.8	58.5	66.6

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

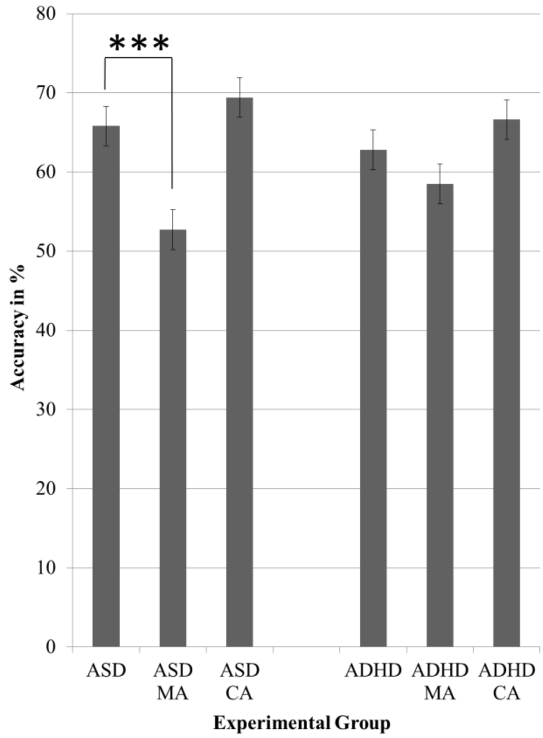


Figure* 8. *Accuracy. Main effect of experimental group on accuracy mean scores, controlled for age. *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

Again, the effect of content was highly significant, see Table 7, showing that place memory accuracy was the highest when locating technical toys (M = 80.4%), in comparison to roleplay (M = 60.1%) and neutral objects (M = 61.3%) which showed very little to no difference in memory performance (see Fig. 9).

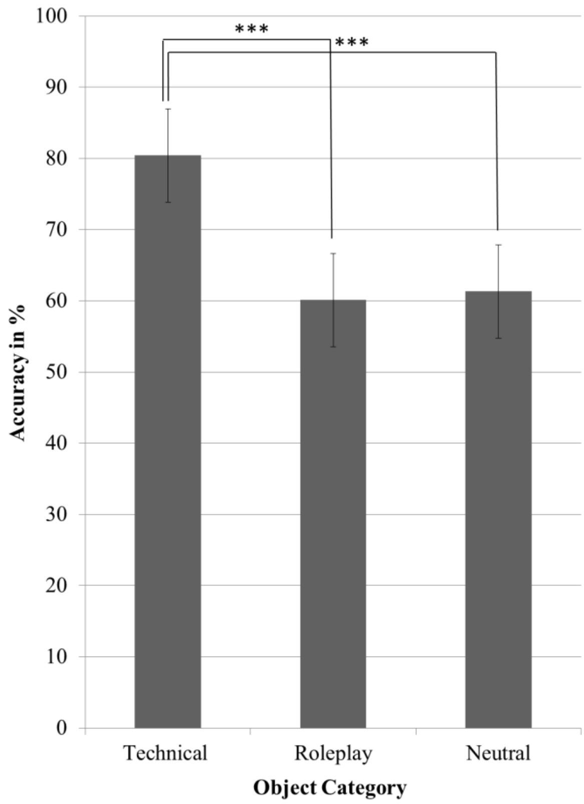


Figure* 9. *Accuracy. The effect of content on place memory performance, controlled for age. *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

The two-way interaction of delay by experimental group was again highly significant, following the same pattern as in the primary analysis without covariates, see Table 9 and Fig. 10.

Table 9

Delay Effect (Same-Object versus Different-Object Delay) on the Accuracy Mean Scores of the ASD, ADHD and Control Groups, controlled for age in month

	Children with ASD		
Delay	ASD clinical	ASD MA controls	ASD CA controls
Same-Object Delay	69.1**	62.4***	77.8***
Different-Object Delay	62.5	43.0	61.0
	Children with ADHD		
	ADHD clinical	ADHD MA controls	ADHD CA controls
Same-Object Delay	68.8***	68.9***	72.4**
Different-Object Delay	56.9	48.1	60.9

Note. T- tests are pairwise comparisons of the same-object against different-object delay per group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

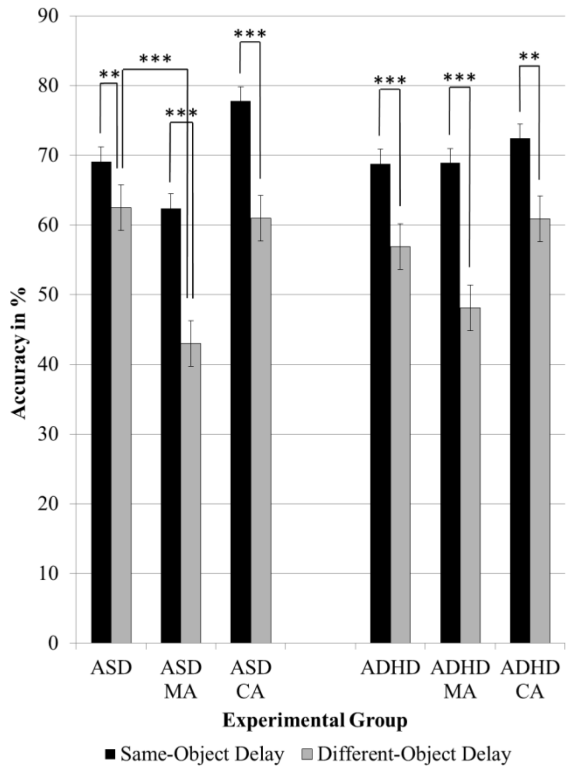


Figure* 10. *Accuracy. The effect of delay on place memory performance of the clinical and control groups, controlled for age. *** = $p < .001$, ** = $p < .01$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

A post-hoc analysis of variance revealed a highly significant difference in place memory accuracy between the ASD group and respective MA controls ($p < .001$) when a new object exemplar was viewed in the delay task. This showed the robust nature of interference with a diminished effect on the children with ASD which occurred independently of age.

The analysis was then conducted with age (in months), verbal mental age (VMA) and Raven (the latter are controls for verbal and visual intelligence) as covariates. This did not only further examine the strength of the delay variable, but also accounted for any differences caused by modality-specific intelligence. The statistical effects obtained for the analysis are shown in Table 10.

Table 10

MANOVA effects of place memory accuracy, controlled for age in month, verbal and visual intelligence (*N*=117)

Statistical Effect	df	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**7.88**	**.000**	**.067**
Object type*Age	2	.898	.409	.008
Object type*VMA	**2**	**3.30**	**.039**	**.029**
Object type*Raven	2	.849	.429	.008
Object type*Group	10	.450	.920	.020
Delay	1	.249	.619	.002
Delay*Age	1	.519	.473	.005
Delay*VMA	1	2.40	.124	.021
Delay*Raven	1	.079	.779	.001
Delay*Group	**5**	**4.90**	**.000**	**.182**
Object type*Delay	2	.018	.982	.000
Object type*Delay*Age	2	1.65	.195	.015
Object type*Delay*VMA	2	1.50	.225	.013
Object type*Delay*Raven	2	.024	.976	.000
Object type*Delay*Group	10	1.04	.414	.045
Between-subject Effects				
Group	**5**	**10.72**	**.000**	**.328**
Raven	1	1.74	.189	.016
VMA	1	.176	.676	.002
Age	1	1.94	.167	.017

Note. Significant effects are set in bold.

Again, the main effect of group was highly significant (see Table 11 and Fig. 11).

Table 11

Accuracy Mean Scores (Group main effect) controlled for age in month, verbal and visual intelligence

Children with ASD			
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	64.1	52.6**	70.2
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	62.5	58.6	67.9

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

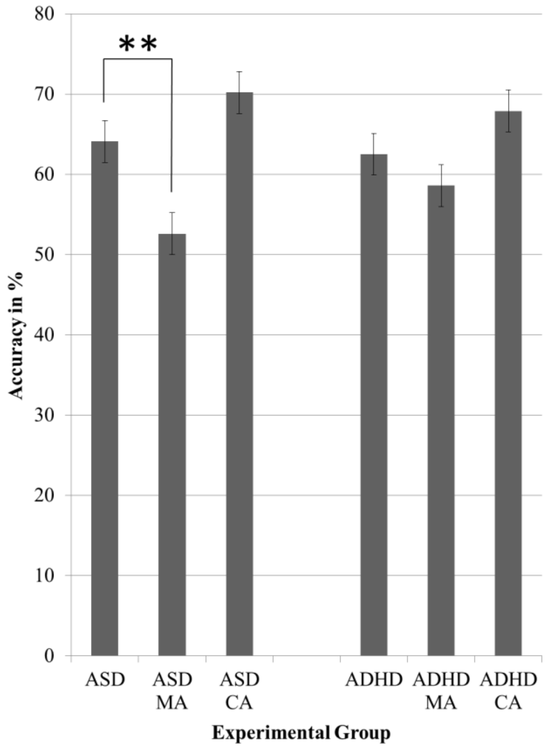


Figure* 11. *Accuracy. Main effect of experimental group on accuracy mean scores, controlled for age, VMA and Raven. ** = $p < .01$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

As in the prior age-controlled analysis, the effect of content remained highly significant (see Table 10), further validating the technical toy preferences of this mostly male sample.

The two-way interaction of delay by experimental group also remained significant (see Table 12 and Fig. 12). This clearly shows the eminent role of object delay in place memory performance of children.

Table 12

Delay Effect (Same-Object versus Different-Object Delay) on the Accuracy Mean Scores of the ASD, ADHD and Control Groups, controlled for age in month, verbal and visual intelligence

Children with ASD			
Delay	ASD clinical	ASD MA controls	ASD CA controls
Same-Object Delay	67.5**	62.7***	78.5***
Different-Object Delay	60.7	42.5	61.8
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Same-Object Delay	68.3***	68.9***	73.5***
Different-Object Delay	56.7	48.2	62.4

Note. T- tests are pairwise comparisons of the same-object against different-object delay per group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

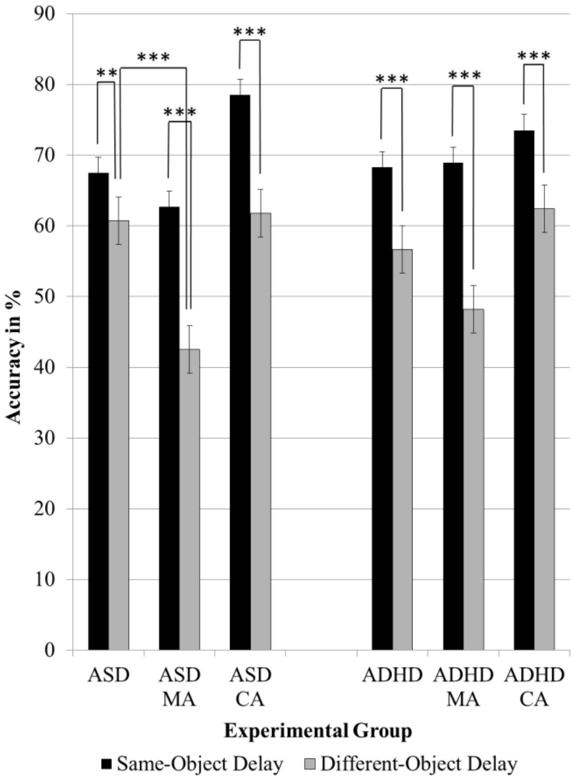


Figure* 12. *Accuracy. The effect of delay on place memory performance of the clinical and control groups, controlled for age, VMA and Raven. *** = $p < .001$, ** = $p < .01$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

An additional two-way interaction of object type by VMA was significant. No significant correlations were found between VMA and place memory accuracy of the technical objects $r(117) = .11$, $p = .216$, roleplay objects $r(117) = .15$, $p = .103$ and neutral objects $r(117) = .12$, $p = .207$. All three correlations were positive.

Among children with autism and ADHD, deficits in visual-motor integration skills are commonly observed (Englund, Decker, Allen & Roberts, 2014), therefore a final analysis was run with age (in months), VMA, Raven and the Bender as covariates. The statistical effects are shown in Table 13.

Table 13
MANOVA effects of place memory accuracy, controlled for age in month, verbal and visual intelligence and the Bender Gestalt (*N*=117)

Statistical Effect	df	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**7.91**	**.000**	**.068**
Object type*Age	2	.624	.537	.006
Object type*VMA	**2**	**3.58**	**.030**	**.032**
Object type*Raven	2	1.81	.167	.016
Object type * Bender	2	1.94	.146	.017
Object type*Group	10	.631	.787	.028
Delay	1	.246	.621	.002
Delay*Age	1	.506	.478	.005
Delay*VMA	1	2.25	.137	.020
Delay*Raven	1	.065	.799	.001
Delay*Bender	1	.000	.996	.000
Delay*Group	**5**	**4.52**	**.001**	**.172**
Object type*Delay	2	.011	.989	.000
Object type*Delay*Age	2	1.69	.186	.015
Object type*Delay*VMA	2	1.29	.278	.012
Object type*Delay*Raven	2	.227	.797	.002
Object type*Delay*Bender	2	.713	.491	.006
Object type*Delay*Group	10	1.04	.411	.046
Between-subject Effects				
Group	**5**	**10.65**	**.000**	**.328**
Raven	1	.800	.373	.007
VMA	1	.050	.823	.000
Bender	1	.633	.428	.006
Age	1	2.21	.140	.020

Note. Significant effects are set in bold.

No additional effects or interactions were significant and the previous significant effects stayed at the same level, see Table 10, page 76, for comparison.

3.2. Reaction Time Analysis

The same analysis of variance was run for reaction times of hits. The statistical effects obtained for the reaction time analysis are shown in Table 14.

Table 14
MANOVA effects of place memory reaction times (*N*=117)

Statistical Effect	df	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**164.14**	**.000**	**.698**
Object type*Group	**10**	**3.51**	**.000**	**.198**
Delay	1	.501	.481	.007
Delay*Group	5	.541	.745	.037
Object type*Delay	**2**	**3.43**	**.035**	**.046**
Object type*Delay*Group	10	.999	.448	.066
Between-subject Effects				
Group	**5**	**3.99**	**.003**	**.220**

Note. Significant effects are set in bold.

A main effect for experimental group was found, showing that ASD children had much slower place memory reaction times (*M* = 11591 ms) than ADHD children (*M* = 7058 ms). The lower place memory accuracy in the ADHD group (versus ASD group) may have been caused by overshooting reaction times.

Planned post-hoc pairwise comparisons within the model revealed a significant difference in reaction times between the ASD group and ASD MA controls (*p* = .033), with ASD children showing significantly slower recall (*M* = 11591 ms) than the MA controls (*M* = 6981 ms). As the MA controls were older, this difference could be age-dependant (see Table 1). Comparisons also revealed a pronounced difference between the ASD group and ASD CA controls (*p* = .003), with ASD children showing significantly slower recall (*M* = 11591 ms) than the CA controls (*M* = 6036 ms). However, no significant effects were found between the ADHD group and the respective controls ($p_s > .05$). This effect is shown in Table 15 and Fig. 13.

Table 15
Reaction Time Mean Scores (Group main effect)

	Children with ASD		
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	11591	6981*	6036**
	Children with ADHD		
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	7058	4758	6347

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

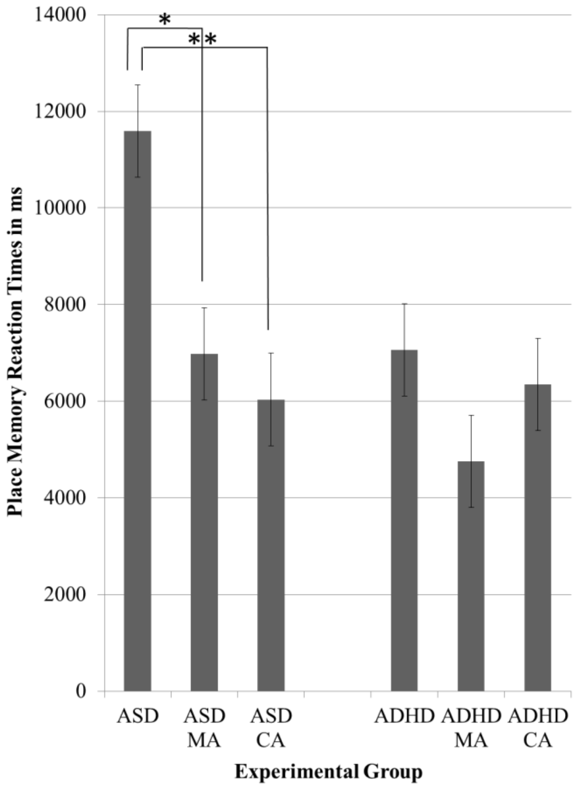


Figure* 13*. Reaction Times. Main effect of experimental group on place memory reaction times. ** = $p < .01$, * = $p < .05$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

There was no significant group by delay effect for reaction times showing that the slower speed of children with ASD was not the reason for their diminished propensity for object interference.

The effect of content was significant, with a pronounced effect size. The speed of place recognition for technical objects was the slowest (*M* = 26034 ms), in comparison to the roleplay (*M* = 7356 ms) and neutral objects (*M* = 7125 ms) which showed little difference in reaction times. Although children were slower at locating technical objects, this particular category had the highest memory accuracy. This reaction-time accuracy trade-off was thus linked to their interest in this particular kind of toy. Post-hoc pairwise comparisons within the model revealed that place memory reaction times for technical objects differed significantly from the roleplay ($p < .001$) and neutral ($p < .001$) objects (see Fig. 14).

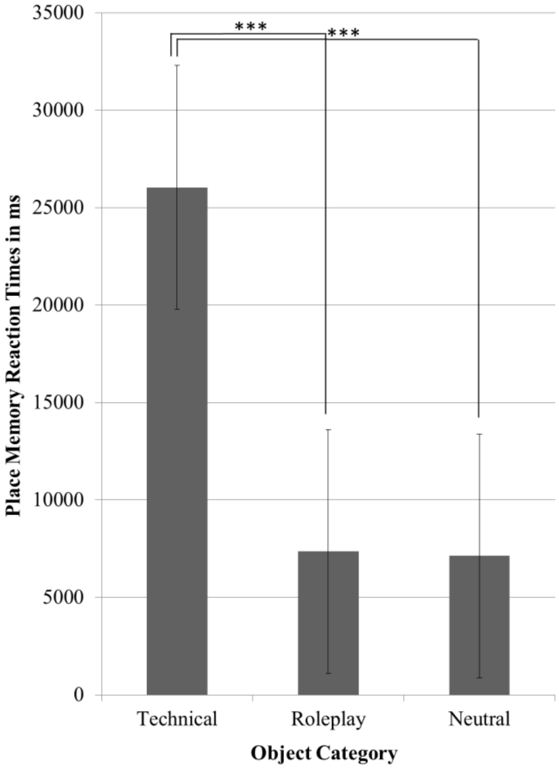


Figure* 14. *Reaction Times. The effect of content on place memory reaction times. *** = $p < .001$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

A two-way interaction of object type by group was significant, showing that all children took longer to locate technical objects, in comparison to roleplay and neutral objects (see Table 16 and Fig. 15), but children with ASD had the slowest place memory for technical toys.

Table 16
Content Effect on the Reaction Time Mean Scores of the Clinical and Respective Control Groups

	Children with ASD		
	ASD clinical	ASD MA controls	ASD CA controls
Technical	44415	27303	23187
Roleplay	9329**	10658**	5468***
Neutral	12760**	5846***	7161***
	Children with ADHD		
	ADHD clinical	ADHD MA controls	ADHD CA controls
Technical	21231	20236	19834
Roleplay	7125***	5304***	6251**
Neutral	6023***	4833***	6127***

Note. T- tests are pairwise comparisons of the technical objects against the roleplay and neutral objects per group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

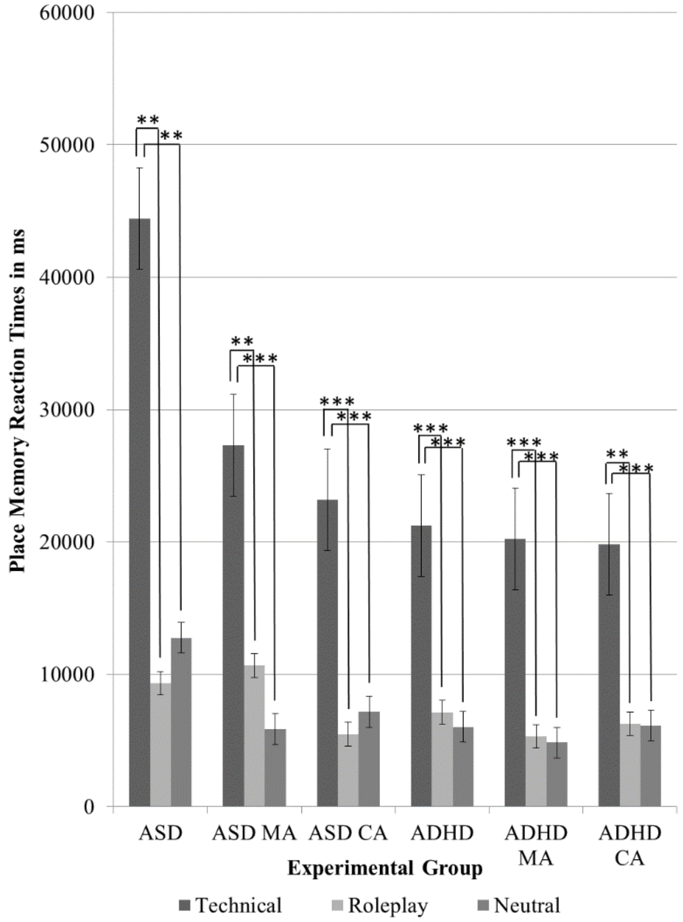


Figure* 15. *Reaction Times. The effect of content on place memory reaction times of the clinical and respective control groups. *** = $p < .001$, ** = $p < .01$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

Between the ADHD and respective control groups, there was little difference in the reaction times pattern. Post-hoc t-tests (two-tailed) confirmed that across all of the experimental groups, place memory reaction times of the location memory for the technical objects differed from those of roleplay and neutral objects ($p_s < .001$).

Post-hoc tests for independent samples showed a significant difference in reaction times for technical toys between the ASD group (M = 44415 ms) and the ASD MA controls (M = 27303 ms) $t(38) = 3.58$, $p = .004$ and ASD CA controls (M = 23187 ms) $t(38) = 2.87$, $p = .009$. This showed the slow reaction times for technical toys in children with ASD. No significant differences were found between the ADHD group and respective MA controls $t(38) = .281$, $p = .781$, as well as between the ADHD group and respective CA controls $t(38) = .176$, $p = .862$. With regards to the roleplay category, there was a significant difference in reaction times between the ASD group (M = 9329 ms) and ASD CA controls (M = 5468 ms) $t(38) = 2.86$, $p = .007$. Children with ASD were slower than CA controls. Other comparisons between the clinical groups and respective controls were not significant ($p_s > .066$). Furthermore, when neutral objects were presented, reaction times differed between the ASD group and ASD MA controls $t(38) = 3.87$, $p < .001$, with autistic children showing slower place memory (M = 12760 ms) than MA controls (M = 5846 ms). This significant difference was also found among ASD children and ASD CA controls $t(38) = 3.22$, $p = .003$. No significant differences were found between the ADHD group and respective MA controls and CA controls ($p_s > .08$).

Furthermore, a two-way interaction of object type by delay was significant. Same-object delay versus a different-object exemplar resulted in faster reaction times, showing accelerated memory for technical and neutral objects. However, this was not the case for items in the roleplay category: When the same object was presented in the filled delay task, reaction times were slower (see Table 17 and Fig. 16).

Table 17
Delay Effect (Same-Object versus Different-Object Delay) on the Reaction Time Mean Scores of the Three Object Categories

	Object Category		
Delay	Technical	Roleplay	Neutral
Same-Object Delay	24609*	8371*	6640
Different-Object Delay	27460	6341	7610

Note. T- tests are pairwise comparisons of the same-object against different-object delay, per object category. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

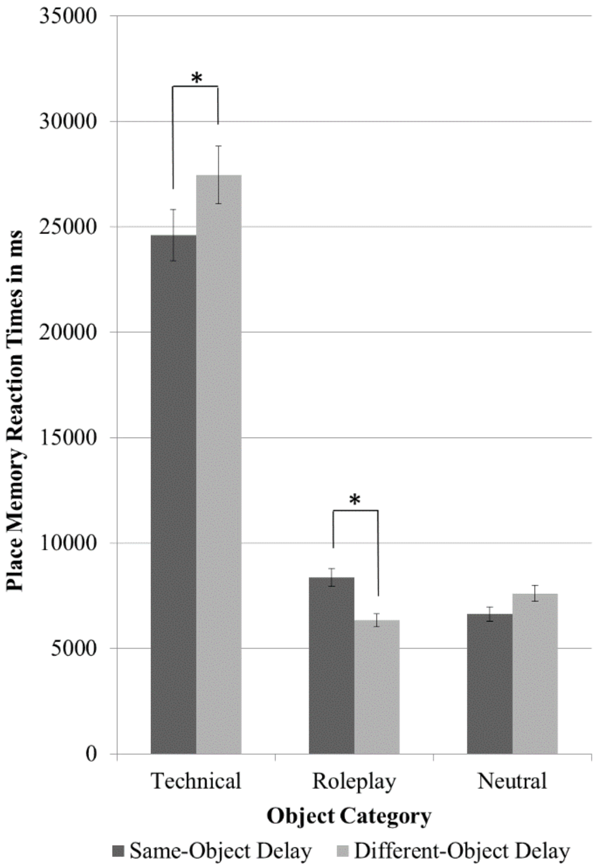


Figure* 16. *Reaction Times. The effect of delay on reaction times of the technical, roleplay and neutral object categories. * = $p < .05$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

Post-hoc t-tests (two-tailed) revealed significant differences between the same and different-object delay in the technical $t(116) = -2.01$, $p = .047$ and roleplay $t(116) = 2.87$, $p = .039$ object categories, whereas the type of delay did not impact the speed of place recognition upon presentation of the neutral objects $t(116) = 1.03$, $p = .305$. While new exemplars of technical objects extended reaction times even further, new human roleplay figures accelerated reaction times.

Some of the notable differences in reaction times between the clinical and respective control groups may be attributed to age. Hence, the reaction time analysis was conducted with age (in months) as a covariate. The statistical effects obtained for the analysis are shown in Table 18.

Table 18
MANOVA effects of place memory reaction times, controlled for age in month (N=117)

Statistical Effect	*df*	*F*	*p*	η2
Within-subject Effects				
Object type	**2**	**6.77**	**.002**	**.088**
Object type*Age	2	.103	.902	.001
Object type*Group	**10**	**3.16**	**.001**	**.184**
Delay	1	3.30	.074	.045
Delay*Age	**1**	**4.02**	**.049**	**.054**
Delay*Group	5	1.20	.317	.079
Object type*Delay	2	2.41	.094	.033
Object type*Delay*Age	2	2.19	.082	.040
Object type*Delay*Group	10	1.53	.134	.099
Between-subject Effects				
Group	**5**	**3.17**	**.012**	**.185**
Age	1	1.24	.270	.017

Note. Significant effects are set in bold.

A main effect for experimental group was found as in the prior analysis in which age was not controlled (see Table 19 and Fig. 17).

Table 19
Reaction Time Mean Scores (Group main effect) controlled for age in month

Children with ASD			
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	11380	6887*	5832**
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	7188	4943	6491

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

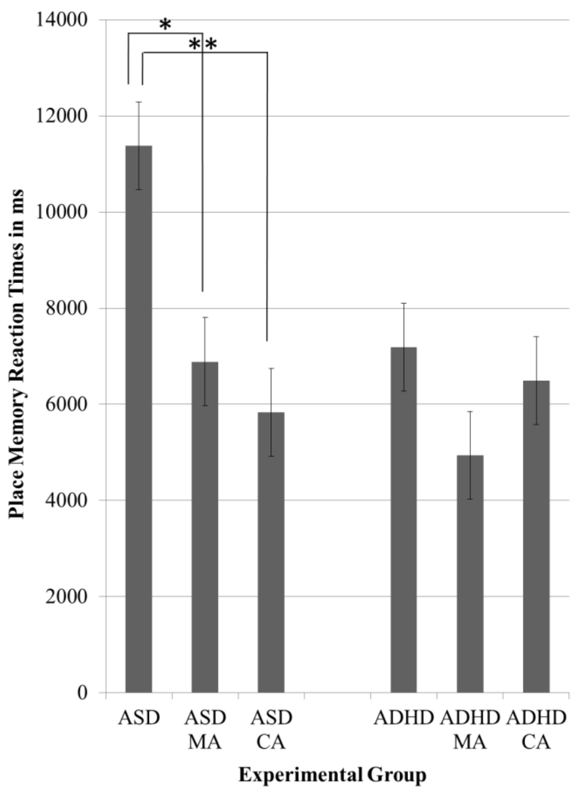


Figure* 17. *Reaction Times. Main effect of experimental group on place memory reaction times, controlled for age. ** = p < .01, * = p < .05 (stars indicate differences in reaction times). Means with standard error (SE) bars.

Planned post-hoc pairwise comparisons within the model revealed a robust pattern of place memory reaction times between the ASD group and ASD MA controls (p = .048), and the ASD group and respective CA controls which remained highly significant (p = .003).

Again, the effect of content was significant showing that place memory reaction times for the technical objects were the slowest (M = 25994 ms) compared to the roleplay (M = 7328 ms) and neutral objects (M = 7072 ms) depicting similar reaction times. Post-hoc pairwise comparisons within the model revealed that place memory reaction times for technical objects differed significantly from the roleplay (p < .001) and neutral (p < .001) objects (see Fig. 18).

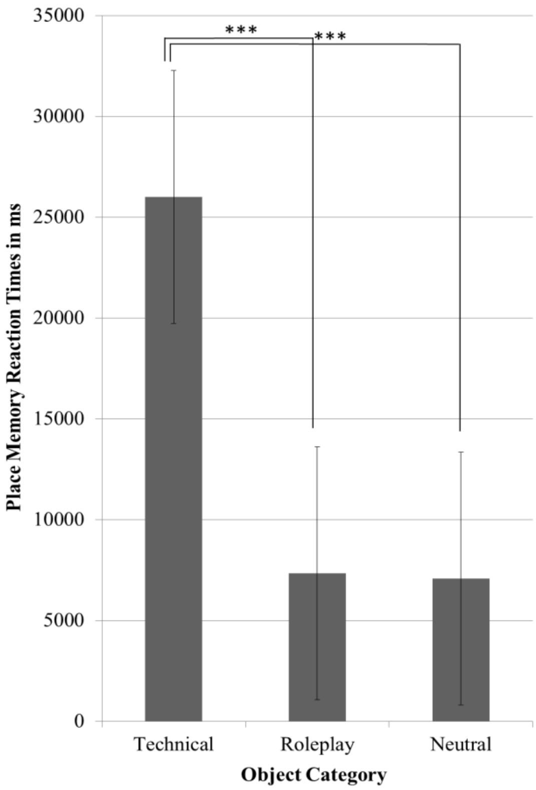


Figure* 18. *Reaction Times. The effect of content on place memory reaction times, controlled for age. *** = $p < .001$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

The two-way interaction of content by group remained significant, following the same pattern as in the primary analysis without covariates, see Table 20 and Fig. 19.

Table 20

Content Effect on the Reaction Time Mean Scores of the Clinical and Respective Control Groups, controlled for age in month

Children with ASD			
	ASD clinical	ASD MA controls	ASD CA controls
Technical	43848	26728	22345
Roleplay	8930**	10253**	4875***
Neutral	12009**	5084***	6045***
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Technical	21824	20872	20350
Roleplay	7542***	5752***	6613**
Neutral	6808***	5676***	6810***

Note. T- tests are pairwise comparisons of the technical objects against the roleplay and neutral objects per group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

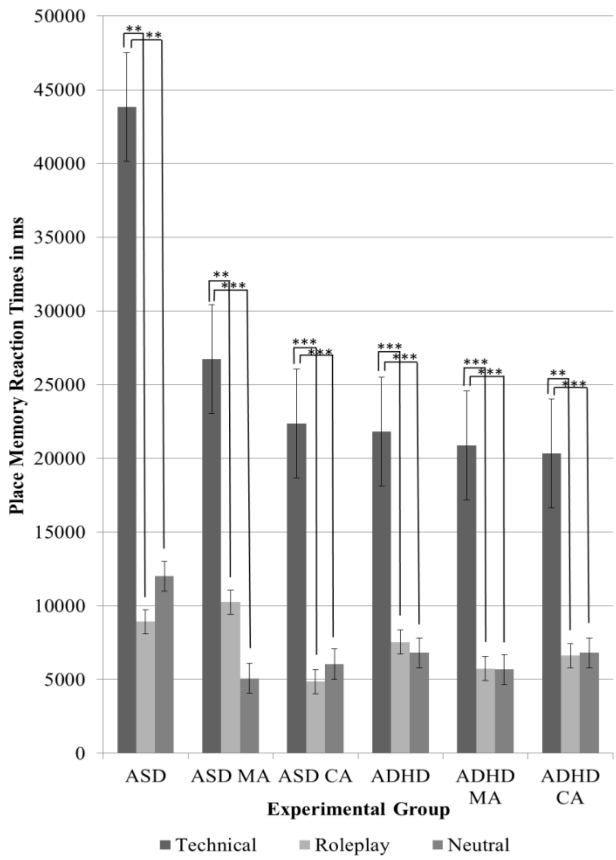


Figure* 19. *Reaction Times. The effect of content on place memory reaction times of the clinical and respective control groups, controlled for age. *** = $p < .001$, ** = $p < .01$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

The object type by delay was no longer significant showing that this effect was dependant on age. Instead the delay effect interacted with age, with a significant negative correlation of $r(117) = -.23$, $p = .013$. A scatterplot (no figure) showed that as age increased, there was a decrease in place memory reaction times when the same object was presented in the filled delay task. However, this was not the case when a new category exemplar was shown during the delay.

Again, a modality-controlled analysis was conducted with age (in months), VMA and Raven as covariates. The statistical effects obtained for the analysis are shown in Table 21.

Table 21
MANOVA effects of place memory reaction times, controlled for age in month, verbal and visual intelligence (*N*=117)

Statistical Effect	df	*F*	*p*	η2
		Within-subject Effects		
Object type	2	.765	.467	.011
Object type*Age	2	2.63	.076	.037
Object type*VMA	**2**	**3.44**	**.035**	**.048**
Object type*Raven	2	.158	.854	.002
Object type*Group	**10**	**2.10**	**.028**	**.134**
Delay	1	2.25	.138	.032
Delay*Age	1	2.18	.145	.031
Delay*VMA	1	.454	.503	.007
Delay*Raven	1	.789	.378	.011
Delay*Group	5	1.35	.255	.090
Object type*Delay	**2**	**3.66**	**.028**	**.051**
Object type*Delay*Age	2	2.77	.066	.039
Object type*Delay*VMA	2	1.28	.282	.018
Object type*Delay*Raven	2	2.19	.116	.031
Object type*Delay*Group	10	1.79	.068	.116
		Between-subject Effects		
Group	5	1.86	.112	.120
Raven	1	.415	.522	.006
VMA	1	.376	.477	.003
Age	**1**	**9.12**	**.004**	**.118**

Note. Significant effects are set in bold.

Surprisingly, the main effect of experimental group did not reach significance anymore. That is, place memory reaction times across the clinical and control groups did not largely differ from one another (see Table 22 and Fig. 20).

Table 22
Reaction Time Mean Scores (Group main effect) controlled for age in month, verbal and visual intelligence

		Children with ASD	
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	19194	14960	11075
		Children with ADHD	
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	12601	10422	11715

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

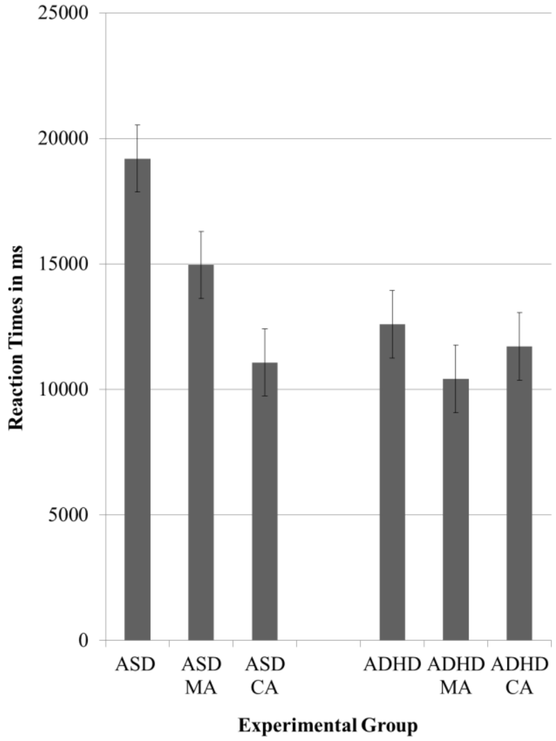


Figure* 20. *Reaction Times. Main effect of experimental group on reaction times, controlled for age, VMA and Raven. Means with standard error (SE) bars.

However, the main effect of age was significant for reaction times, with a significant negative correlation of $r(117) = -.24$, $p = .033$. A scatterplot (no figure) showed that the older the children, the faster the place memory. This acceleration with age is what studies with typically developing children usually show. If showed in this study, too, when controlling for age and intelligence.

The two-way interaction of object type by VMA was significant. No significant correlations were found between VMA and place memory reaction times for the technical objects $r(117) = -.03$, $p = .809$, roleplay objects $r(117) = -.07$, $p = .445$ and neutral objects $r(117) = -.09$, $p = .333$. All three correlations were negative.

The effect of content by group was significant again showing that this interaction occurred independently of both visual and verbal intelligence.

The delay by age effect found in the age-controlled analysis was no longer significant; however the content by delay effect was significant, see Table 21.

When the same-object delay versus a different-object exemplar was presented in the filled delay task, this resulted in faster reaction times, showing accelerated memory for technical and neutral objects. However, this was not the case for items in the roleplay category: Reaction times were in fact slower when the same object was presented in the delay task (see Table 23 and Fig. 21).

Table 23

Delay Effect (Same-Object versus Different-Object Delay) on the Reaction Time Mean Scores of the Three Object Categories, controlled for age in month, verbal and visual intelligence

	Object Category		
Delay	Technical	Roleplay	Neutral
Same-Object Delay	24061*	8214*	6495
Different-Object Delay	27625	6299	7274

Note. T- tests are pairwise comparisons of the same-object against different-object delay, per object category. *p* < .05 = *, *p* < .01 = **, *p* < .001 = ***

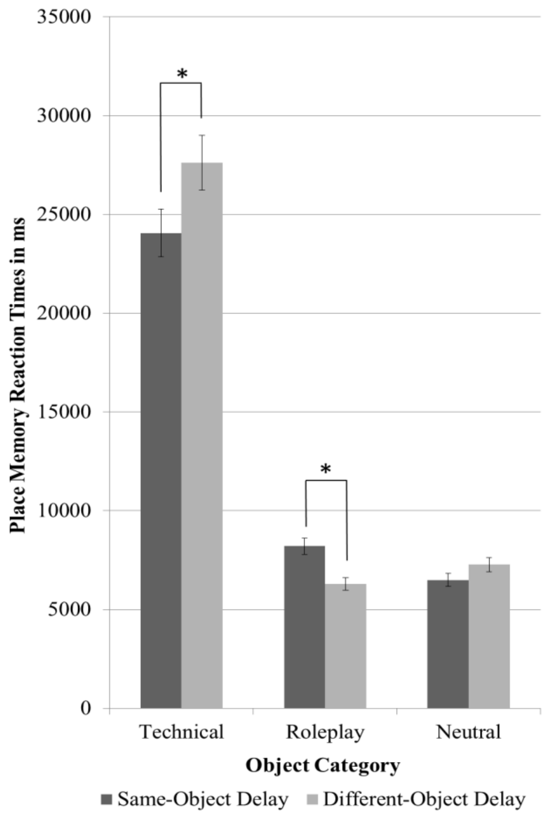


Figure* 21. *Reaction Times. The effect of delay on reaction times of the technical, roleplay and neutral object categories, controlled for age, VMA and Raven. * = *p* < .05 (stars indicate differences in reaction times). Means with standard error (SE) bars.

Post-hoc t-tests (two-tailed) revealed significant differences between the same and different-object delay in the technical $t(116) = -2.22$, $p = .040$ and roleplay $t(116) = 2.77$, $p = .047$ object categories, whereas delay did not impact the speed of place recognition when neutral objects were presented $t(116) = 1.13$, $p = .460$. While children reacted in general somewhat quicker in the place test after having seen the same exemplar in the delay, having seen a human lego or playmobil warrior or a doll extended reaction times in the place test. This suggested that especially human figures could act as effective distractors. This effect was the same for all children, controlled for age and intelligence.

Both children with ASD and ADHD possess motor deficits which may impact reaction times (Mayes & Calhoun, 2007). Thus, a final analysis was run with age (in months), VMA, Raven and the Bender as covariates. The statistical effects obtained for the analysis are shown in Table 24.

Table 24
MANOVA effects of place memory reaction times, controlled for age in month, verbal and visual intelligence and the Bender Gestalt (N=117)

Statistical Effect	df	*F*	*p*	η2
Within-subject Effects				
Object type	2	.824	.441	.012
Object type*Age	2	2.60	.078	.037
Object type*VMA	**2**	**3.80**	**.025**	**.054**
Object type*Raven	2	.158	.854	.002
Object type * Bender	2	.453	.637	.007
Object type*Group	**10**	**1.53**	**.035**	**.102**
Delay	1	2.15	.147	.031
Delay*Age	1	2.15	.147	.031
Delay*VMA	1	.242	.624	.004
Delay*Raven	1	.930	.338	.014
Delay*Bender	1	.171	.681	.003
Delay*Group	5	1.29	.281	.088
Object type*Delay	**2**	**3.60**	**.030**	**.051**
Object type*Delay*Age	2	2.74	.068	.039
Object type*Delay*VMA	2	1.05	.351	.015
Object type*Delay*Raven	2	1.98	.143	.029
Object type*Delay*Bender	2	.078	.925	.001
Object type*Delay*Group	10	1.70	.087	.113
Between-subject Effects				
Group	**5**	**1.37**	**.000**	**.093**
Raven	1	.266	.608	.004
VMA	1	8.32	.284	.110
Bender	1	.114	.737	.002
Age	**1**	**8.99**	**.004**	**.118**

Note. Significant effects are set in bold.

The main effect of experimental group emerged again, see Table 25.

Table 25
Reaction Time Mean Scores (Group main effect) controlled for age in month, verbal and visual intelligence and the Bender Gestalt

Children with ASD			
	ASD clinical	ASD MA controls	ASD CA controls
Place Memory	11846	7202	5644*
Children with ADHD			
	ADHD clinical	ADHD MA controls	ADHD CA controls
Place Memory	7101	4775	6238

Note. T- tests are pairwise comparisons of controls against the respective clinical group. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

Multiple pairwise comparisons within the model only revealed a significant difference in place memory reaction times between the ASD group and ASD CA controls ($p = .026$), but not with respective MA controls, see Fig. 22. This means that ASD children were slow for their age.

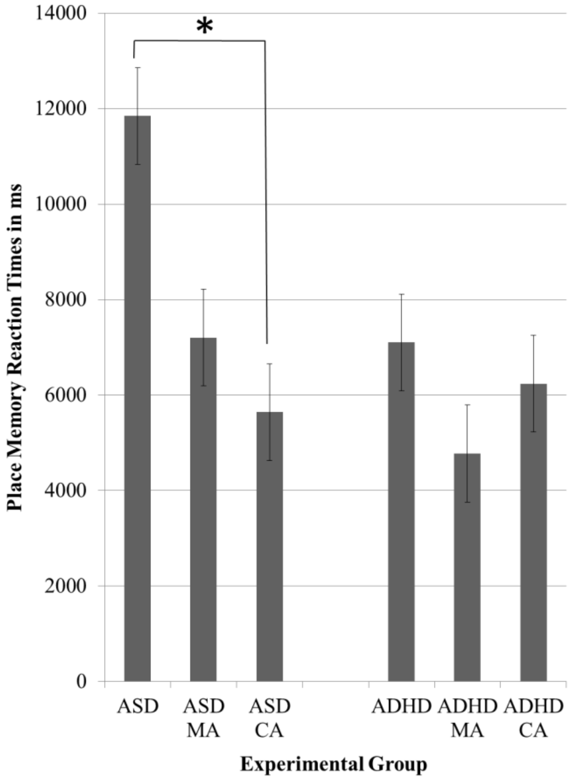


Figure* 22*. Reaction Times. Main effect of experimental group on place memory reaction times, controlled for age, VMA, Raven and the Bender Gestalt. * = $p < .05$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

The main effect of age and the interactions of content by VMA, content by group and content by delay, see Table 24, were robust. This clearly shows the eminent role of the effect of object type on children's place memory reaction times.

3.3. Control with the Covariate Spatial Binding

The Common Region Test (CRT) measures spatial binding strategies in preschool and school aged children (Lange-Küttner, 2006). It is also a predictor for spatial memory. On the one hand, object-place binding predicts enhanced object memory, whilst on the other hand; object-area binding predicts enhanced location memory and systematic learning (Lange-Küttner, 2013). Hence, in the current study, it was hypothesized that better performance on the place memory task would somewhat be associated with object-region binding.

3.3.1 Analysis of Spatial Binding Strategies (Common Region Test, CRT)

Chi-Square analysis (two-sided) showed a significant effect of spatial binding with the ADHD clinical group and respective controls, $x^2(4, 117) = 12.62$, $p = .013$, phi = .46. With regards to the ASD groups, no significant spatial coding effects were found $p > .05$, see Table 26 and Fig. 23.

Table 26
Common Region Coding by Group (percentages per group)

Common Region Test (CRT)				
Group	Object-Place	Unsystematic	Object-Region	Total
ASD	3 (15.8%)	14 (73.7%)	2 (10.5%)	19
ASD MA	4 (21.1%)	8 (42.1%)	7 (36.8%)	19
ASD CA	5 (26.3%)	8 (42.1%)	6 (31.6%)	19
ADHD	3 (15.0%)	14 (70.0%)	3 (15.0%)	20
ADHD MA	5 (25.0%)	4 (20.0%)	11 (55.0%)	20
ADHD CA	1 (5.0%)	10 (50.0%)	9 (45.0%)	20
Total	21 (17.9%)	58 (49.6%)	38 (32.5%)	117

Note. Observed frequencies are set in brackets. MA and CA are the respective controls.

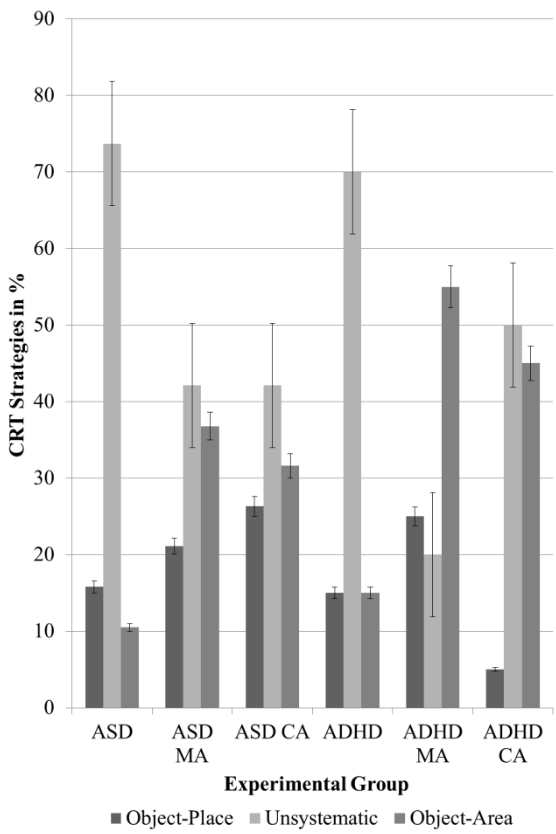


***Figure* 23.** Allocating spatial boundaries in the Common Region Test (CRT) by ASD and ADHD children and respective control groups. Means with standard error (SE) bars.

The table and graph show that both clinical groups have the highest percentage of unsystematic coders. For this reason, in the following analysis, unsystematic coders were not excluded. In previous studies with TD children, unsystematic coders were excluded as very few children coded in this manner (Lange-Küttner, 2010a; 2010b; 2013; Lange-Küttner & Küttner, 2015). Two smaller accuracy and reaction time analysis of variance were conducted for the ASD children and controls, and for the ADHD children and control groups, with the CRT as a between-subject variable. Thus, the effect of the CRT was tested per clinical group plus controls. To ensure that the minimum expected cell size was larger than 5, we combined object-place and object-area binding into one level and renamed this variable as 'systematic' coding. Therefore, the CRT comprised of two levels: systematic and unsystematic coding.

3.3.1.1 Accuracy (CRT Strategies)

A 2 (delay) by 3 (object type) by 3 (experimental groups) by 2 (CRT) MANOVA, with repeated measures on the first and second factor and verbal mental age (VMA), Raven, age (in months) and the Bender Gestalt as covariates were analyzed. All statistical values were reported within the text.

ASD group. No significant spatial binding effects were found when the analysis was run without covariates and when age (in months) was accounted for ($p_s > .062$). However, a three-way interaction of object type by delay by CRT was significant F (2, 117) = 3.36, p = .039, $\varepsilon^2 = .06$, with the inclusion of age (in months), VMA and Raven as covariates. Place memory accuracy of the systematic and unsystematic coders was always higher when the same object (versus different-object exemplar) was viewed in the delay task. This pattern was evident across all categories of objects (see Table 27).

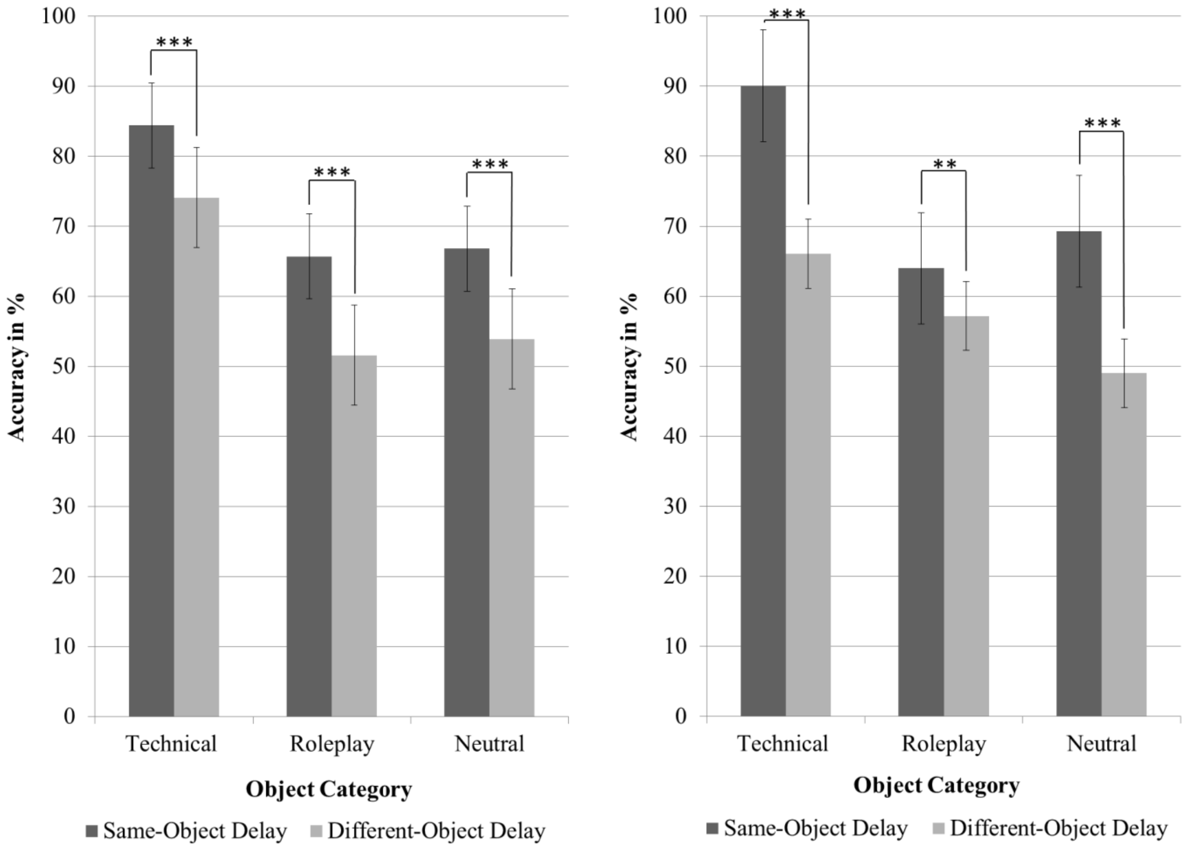
Table 27

Delay Effect (per Object Category) on the Accuracy Mean Scores of the Systematic and Unsystematic Coders in the ASD and ADHD Groups, controlled for age in month, verbal and visual intelligence

	ASD Systematic Coders		
Delay	Technical	Roleplay	Neutral
Same-Object Delay	84.4***	65.7***	66.8***
Different-Object Delay	74.1	51.6	53.9
	ASD Unsystematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	90.1***	64.0**	69.3***
Different-Object Delay	66.1	57.2	49.0
	ADHD Systematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	91.4***	70.0***	71.9***
Different-Object Delay	71.2	56.2	58.9
	ADHD Unsystematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	82.6***	65.8***	68.8***
Different-Object Delay	70.3	45.2	52.1

Note. T- tests are pairwise comparisons of the same-object against different-object delay for systematic and unsystematic coders across the three object categories. $p < .05$ = *, $p < .01$ = **, $p < .001$ = ***

In the ASD group, those children who coded unsystematically were affected by object interference to a greater degree (technical: M = 66.1%, roleplay: M = 57.2%, neutral: M = 49.0%, see Fig. 24). One could say that this indicates a lack of cognitive control over object features.



(A) ASD Systematic Coders (B) ASD Unsystematic Coders

Figure* 24. *Accuracy. The effect of delay on place memory performance across the three object categories, for (A) systematic and (B) unsystematic coders in the ASD groups. ** = $p < .01$, *** = $p < .001$ (stars indicate differences in accuracy). Means with standard error (SE) bars.

Post-hoc t-tests (two-tailed) revealed that all comparisons of the same and different-object delay were statistically different ($p_s < .001$), but Fig. 24 shows that the difference was especially pronounced for technical objects where unsystematic coders with ASD were more interfered by a new technical and neutral exemplars in the delay, but less so by human roleplay figures.

The three-way interaction retained its significance even when the analysis was run with age (in months), VMA, Raven and the Bender as covariates F (2, 117) = 3.23, $p = .044$, $\varepsilon^2 = .06$.

ADHD group. Spatial binding strategies did not have an effect on place memory accuracy performance, even when the covariates were considered ($p_s > .082$).

3.3.1.2 Reaction Times (CRT Strategies)

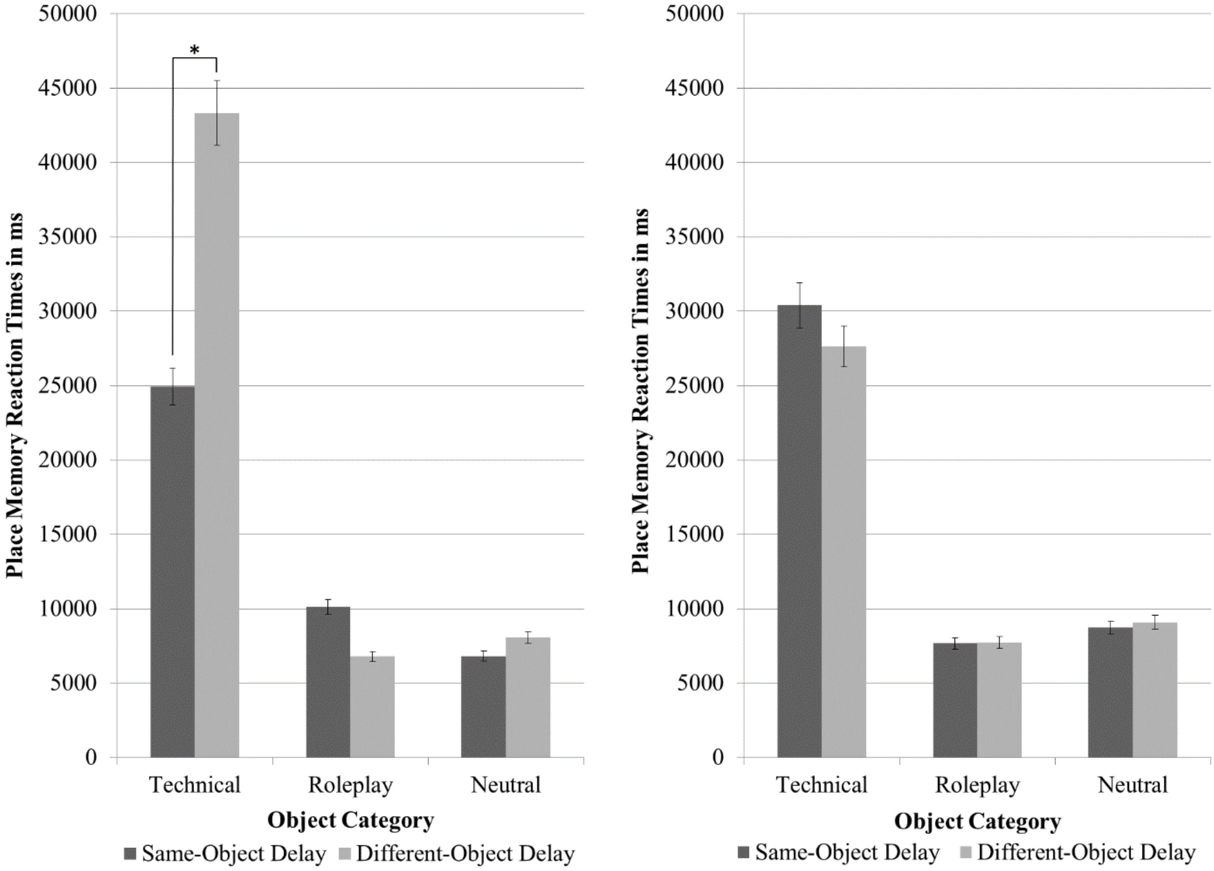
The same analysis of variance was run for reaction times. ***ASD group.*** A three-way interaction of object type by delay by CRT was significant F (2, 117) = 6.13, p = .004, ε^2 = .18. Post-hoc t-tests (two-tailed) revealed that all comparisons of the same against different-object delay were statistically non-significant (p_s > .066), with the exception of the technical objects among ASD systemizers t (57) = -2.15, p = .037, see Table 28.

Table 28
Delay Effect (per Object Category) on the Reaction Time Mean Scores of the Systematic and Unsystematic Coders in the ASD and ADHD Groups

	ASD Systematic Coders		
Delay	Technical	Roleplay	Neutral
Same-Object Delay	24955*	10126	6819
Different-Object Delay	43323	6788	8062
	ASD Unsystematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	30403	7677	8728
Different-Object Delay	27631	7735	9099
	ADHD Systematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	19839	5509	6363
Different-Object Delay	21581	5197	7262
	ADHD Unsystematic Coders		
	Technical	Roleplay	Neutral
Same-Object Delay	16796	7131	8113
Different-Object Delay	15723	4450	9649

Note. T- tests are pairwise comparisons of the same-object against different-object delay for systematic and unsystematic coders across the three object categories. p < .05 = *, p < .01 = **, p < .001 = ***

Place memory reaction times of the ASD systematic coders benefitted more from the repetition (technical: M = 24955 ms, roleplay: M = 10126 ms, neutral: M = 6819 ms), than unsystematic coders (technical: M = 43323 ms, roleplay: M = 6788 ms, neutral: M = 8062 ms, see Fig. 25).



(A) ASD Systematic Coders (B) ASD Unsystematic Coders

Figure* 25. *Reaction Times. The effect of delay on place memory reaction times across the three object categories, for (A) systematic and (B) unsystematic coders in the ASD groups. * = $p < .05$ (stars indicate differences in reaction times). Means with standard error (SE) bars.

Further post-hoc t-tests (two-tailed) found that among systemizers and non-systemizers, place memory reaction times of the technical objects for the same-object delay differed significantly from the roleplay and neutral object categories ($p_s < .001$). However, the different-object delay was only pronounced in systematic coders for the place memory reaction times of the technical objects.

The three-way interaction retained its significance when the analysis was conducted with age (in months) as a covariate F (2, 117) = 5.10, p = .009, ε^2 = .15, with the addition of VMA and Raven F (2, 117) = 5.04, p = .010, ε^2 = .16 and likewise when the Bender was added as a fourth covariate F (2, 117) = 4.77, p = .013, ε^2 = .16.

ADHD group. Spatial binding strategies did not impact place memory reaction times, even when the covariates were considered (p_s > .301).

4. DISCUSSION

In the domain of visuo-spatial memory, overshadowing of a place by an object often results in the lack of place learning in children, especially younger children: The object becomes the focus of attention; hence children fail to direct their attention towards the location occupied by the object (Lange-Küttner, 2010b). The ADA (Association-Disassociation-Model) predicts that at this stage, the object stands for the place (object-place binding) (Lange-Küttner, 2008). Having said that, when children were repeatedly experiencing the same location as occupied by the same object, they did show place learning (Lange-Küttner & Küttner, 2015). The present study closely examined spatial memory in autistic, ADHD and typically developing control children. It was predicted that ASD children in contrast to ADHD children and matched neurotypicals would exhibit better place memory because their focus was less likely to be captured by the meaningful objects, and that this would be especially pronounced for the class of technical toys which they may particularly fancy in comparison to social role-playing toys. The results of the study confirmed this prediction showing the relatively better performance of ASD children compared to the respective mental age control children in the location memory task. However, technical toys such as cars were the best placeholders for all children independently of special needs. This validates the intense interests of both neurotypicals and the clinical groups in this particular kind of toy.

The study also tested whether imposing a filled delay task would impact children's place memory. It was predicted that the same-object delay would facilitate place memory, as repeated exposure to a stimulus is a mechanism that leads to memory consolidation (Ebbinghaus, 1964; Lange-Küttner, 2011; Lange-Küttner & Küttner, 2015). In contrast, a different-object exemplar would require a disassociation of the previously experienced object-place binding in the presentation phase. In this way, it would act as a place memory distractor. Results revealed that the same-object exemplar in the delay (versus a different-object exemplar) benefitted children's place memory thereafter. In fact, results showed a very robust effect of the delay repetition on place memory performance.

In the following sections, the present findings will be discussed drawing links to previous literature and relevant theories within the domain. The discussion will begin by addressing children's memory for objects' location and the effect of content on place memory. Following this, the effect of the interference task (same-object delay versus different-object exemplar) will be considered and children's spatial binding strategies (systematic versus unsystematic coders) will be discussed in relation to their impact on place memory performance.

4.1. Place Memory Performance Levels in TD, ASD and ADHD Children

The primary objective of the study was to explore place memory in autistic, ADHD and typically developing children. Results of the current study found that autistic children had better place memory performance compared to the ADHD children and respective mental age controls. Nonetheless, indistinguishable performance was observed between ASD children and matched chronological age controls, as well as ADHD children and matched controls. This clearly showed that autistic children had better location memory than would have been predicted by their mental age, but commensurate with CA controls. In line with our prediction, autistic children demonstrated an intact location memory (Ozonoff and Strayer, 2001). The findings can be explained in the light of the cognitive theory of central coherence (Frith, 1989). Children were instructed to focus their attention towards the place and not the object per se. As reflected in their performance, this worked to the advantage of autistic children because 1) they pay little attention to meaningful contingencies. In the current study, they were less bound by a focus on the objects (real-life, meaningful entities) hence the comparatively higher place memory and 2) the sole focus on individual places (object-in-place), meant that children were required to focus on a small part of the grid and not the grid as a whole. For children with ASD, this was not effortful due to their local enhancement. One may also reason this as stemming from an integrative weakness: ASD children could perhaps ignore all the other places in the grid, that is, they would have an increased ability to filter out the context of the entire grid. Thus weak central coherence may be an advantage for place memory when focus on an individual place is required. In contrast, poorer performance of the typically developing children (MA controls) reflects a difficulty in resisting the gestalt over constituent parts (Koffka, 1935). As the grid consisted of various places, this may have led to confusion regarding which place was actually occupied – a common error reported when the size of the grid was large, resulting in poor recall of the exact place (Lecerf & Roulin, 2009). Furthermore, the ASD spatial memory advantage found in the present study is contradictory to that of existing literature, which demonstrates significant impairments in spatial working memory among autistic children (Williams, Goldstein, Carpenter & Minshew, 2005; Williams, Goldstein & Minshew, 2005; 2006; Kercood, Grskovic, Banda & Begeske, 2014; Wang et al., 2017). These differential results can be explained by the fact that in the majority of these studies, multiple object procedures are employed (versus a single item-location binding in the current study), which tend to exert a greater cognitive load on working memory, thus require attentional resources to support task performance: Studies have evidenced that executive attentional resources are compromised in children with ASD (Hill, 2004; Rajendran & Mitchell, 2007), potentially contributing to poor performance on spatial working memory tasks, such as the block recall task.

A slight but not significant performance impairment was noted among ADHD children when compared to ASD children and matched CA controls. In the current task, the spatial region was delimited by spatial boundaries (grid array) and children were required to focus on one place of many. This may have posed difficulty for ADHD children since they are less able to confine their visual attention (Shalev & Tsal, 2003). Contrary to research indicating that children with ADHD possess significant location memory deficits (Westerberg et al., 2004; Reck et al., 2010), the current findings showed that this may not be the case. The place memory task consisted of numerous trials which meant that children had the opportunity to learn the requirements of the task and an opportunity to 'learn the task', potentially resulting in ADHD children performing within normal limits. Although this was an unexpected result, it was in agreement with the affirmation by Barkley (1977) that functional difficulties in ADHD children may be attributed to performance and not skill deficits per se. Additionally, it is important to consider that research underpinning ADHD impairments in spatial memory use procedures which are high in executive attention resource demand, just like those employed in ASD research. Thus, due to challenged attentional resources in ADHD children (Rapport, Friedman, Eckrich & Calub, 2018), task performance is undermined. In contrast, the current spatial memory task would require minimal attentional resources, which may also explain the comparatively indistinguishable performance of ADHD children.

When place memory was controlled for age, the group effect remained significant. This showed that the effect occurred independently of age. In accordance with the developmental trajectory, one would expect the older MA controls to have better place memory than the younger ASD children as accuracy of spatial memory shows greater proficiency with age (Bayliss, Jarrold, Baddeley, Gunn & Leigh, 2005; Cestari, Lucidi, Pieroni & Rossi-Arnaud, 2007; Klingberg, 2006). However, this was not the case: When the age factor was ruled out, the effect of group was still significant. In one such study by Lange-Küttner (2010a), socio-economic status (SES) was a more powerful predictor for spatial memory than age in boys, whereas spatial memory of girls' was greatly influenced by age. Similarly, in the present study, place memory performance of the predominantly male sample was not mediated by age. Instead, children's cognitive processing styles seem to play a contributory role in their memory for places.

Interestingly, the group effect did not only occur independently of age, but also of modality-specific intelligence and the Bender. As evident in Table 2, all children performed indistinguishably on the measure assessing verbal intelligence because this was how the groups were matched, reflected by their BPVS scores. Hence, the language impairments noted in children with autism (Kjelgaard & Tager-Flusberg, 2001), could not bear on the place memory task, for instance, if naming places would have been a viable strategy. Therefore, these comparable scores may explain why differences in verbal intelligence did not impact children's place memory. It is also worth noting that an effect of non-verbal intelligence was absent. In a study by Shah and Frith (1993), the authors found that heightened performance on the block design task appeared to be independent of non-verbal intelligence, likewise evidenced in the present study but with a different spatial task.

An analysis of place memory reaction times revealed that ASD children had much slower reaction times than ADHD children and the respective ASD controls. Similar reaction time differences between the ADHD group and matched controls were not evident. Despite the fact that ASD children had better place memory performance, they were slower in their place recognition, especially for technical toys as revealed by an interaction of object type by group. This reaction-time accuracy trade-off is commonly observed in children aged 7-to 9-years, as they usually can improve either reaction times or accuracy, but not both (Mackey, Hill, Stone & Bunge, 2011). Furthermore, the comparatively lower place memory accuracy in the ADHD group may have been caused by overshooting reaction times, as they maintained an accelerated pace despite making errors. Research has shown that it is vital children learn to slow down after making errors (Sokhadze et al., 2010; Vlamings, Jonkman, Hoeksma, van

Engeland & Kemner, 2008; Wilding, Munir & Cornish, 2001) because faster responses do not necessarily lead to better recall (Cowan et al., 2006).

The effect of group for reaction times was still significant when controlled for the age factor, showing that the effect was not dependent on differences in age. Although age-dependent improvements in both place memory accuracy and reaction times were not tracked, age was expected to impact children's reaction times. In the present study, this effect of age was found when controlling for age, intelligence and visual-motor integration skills: The older the children, the faster the place memory, as shown by studies with typically developing children (Lange-Küttner, 2010b; 2012). This may also explain why older ASD MA controls were faster than younger ASD children.

Interestingly, it seems as though the group effect for place memory reaction times was hinged on children's intelligence: When differences in IQ levels were accounted for, the effect was no longer significant. This finding to some extent can be explained in the light of previous literature (Fry & Hale, 2000; Neisser et al., 1996), whereby studies with neurotypicals have demonstrated well-established correlations between processing speed and intelligence, precisely fluid intelligence (assessed via the Raven). It is worth mentioning that these studies were not specifically looking at the relationship between the speed of place recognition and intelligence, instead, a more general relationship between reaction times and intelligence. Hence the current place memory study may pave the pathway to investigate this link further.

Unlike the reaction time analysis in which intelligence was controlled for, the effect of group did re-emerge as a consequence of ruling out children's visual-motor integration skills, showing a difference in performance levels only between the ASD group and ASD CA controls. This meant that autistic children were considerably slow for their age. However, ASD children did not differ from their respective MA controls. Therefore, one could infer that visual-motor integration skills played a role in the ASD-ASD MA reaction time difference which was evident in the analyses without the addition of covariates and when age was controlled. Several studies have found that children with autism versus typically developing children exhibit slower reaction times (Rinehart, Bradshaw, Brereton & Tonge, 2001; Donk & Theeuwes, 2003; Landry, Mitchell & Burack, 2009). Even though these studies investigated the overarching ASD-reaction time association, factors such as delays in motor movement development (Mayes & Colhoun, 2007) can be attributed to the slower place recognition in ASD.

In essence, factors such as information processing styles (global versus local), executive attentional control, cognitive load, age, intelligence and visual-motor integration skills may have contributed to the place memory accuracy and reaction time performance of the clinical and respective control groups.

4.2. Content Effects on Children's Place Memory Performance

As predicted, the type of content presented during the memory task also impacted children's memory for locations at test. Remarkably high place memory accuracy for the places of technical objects was found, in comparison to roleplay and neutral placeholders which showed almost no difference in memory performance. This depicts that the technical toys had more power to denote a place, as well as implicating the main attraction of technical objects for this mostly male sample. Baron-Cohen and Wheelwright (1999) found that ASD children and neurotypicals, who were in the majority boys, displayed a stronger preference for vehicles, computers and machines, as opposed to an interest in "people". In the context of the present findings, the objects in the roleplay category, to some extent did represent 'people orientated objects' such as human roleplay figures and dolls, hence the comparatively lower accuracy when recalling the locations of these objects. Indeed, the results of the study by Baron-Cohen and Wheelwright (1999) together with other research (South, Ozonoff &

McMahon, 2005; Lam, Bodfish & Piven, 2008; Brown, Lam, Holtzclaw, Dichter & Bodfish, 2011) produced group-specific results, that is, they were reflective of the intense interests manifested by ASD children and neurotypicals only. However, these findings were congruent with frequently reported gender-stereotyped categories of toy choice (Maccoby, 1998; O'Brien & Huston, 1985), so we can be confident that they are prevalent among the majority of boys, including those in the sample of the current study, irrespective of their group identity. Moreover, the content effect was still significant when place memory was controlled for age, intelligence and visual-motor integration skills, all of which showed superiority in locating technical objects. This suggests that the content effect was independent of the covariates, further validated by the fact that interactions between object type and the covariates were all non-significant: Even when the interaction effect between content and VMA was significant, supplementary correlational analysis disproved this link.

An analysis of place memory reaction times showed that children in the clinical groups and neurotypicals were slower in recalling the location of technical objects, compared to the roleplay and neutral objects – an interaction effect that was very robust. Higher place memory accuracy for the technical objects was associated with slower place recognition. One can think of this as a reaction-time accuracy trade-off. This trade-off was thus caused by children's interest in this particular kind of toy, leading to presumably prolonged visual scanning in order to increase location accuracy thereafter. Children were determined to 'get it right'. It is worth noting that the effect of content on place memory reaction times had nothing to do with age, but may somewhat be dependent on intelligence and visual-motor integration skills as it was no longer significant when controlling for these two variables.

These findings lend further support to the existing body of literature in the domain of intense and circumscribed interests, as well as extending previous research which predominately focuses on interests in typically developing children, individuals with ASD and Asperger's syndrome (Rutter, 1978; South, Ozonoff & McMahon, 2005; Yeargin-Allsopp et al., 2003), but little was known about these interests in children with ADHD which the current study has addressed.

4.3. The Same versus Different Object Exemplar in the Delay: Two Types of What-Interference

The two dimensions of the delay task measured two different aspects that may influence children's place memory. On the one hand, it was predicted that the same-object delay would facilitate place memory, whilst on the other hand; the presentation of a different-object exemplar would have a somewhat disruptive effect as it would require a dissociation of the object-place binding that was established in the presentation phase. In this way, the positive impact of repetition of the object-place binding versus the negative impact of interference caused by the necessary disassociation was investigated with the delay task, just looking at a category exemplar for a limited time.

The present study showed that the same-object facilitation was a very robust effect as it was important for both place memory accuracy and reaction times. Results revealed that when children saw the same object in the delay task, identical to that object occupying several places seen in the presentation phase, memory performance was significantly better than if a new interference object exemplar was presented. This coincides with the existing repetition literature: Research has suggested that stimulus repetition may act like a memory "refresher" by re-activating the memory traces for the stimulus via the deployment of executive attentional resources (Camos & Barrouillet, 2011; Logie & Della Sala, 1999). Similarly, other studies have concluded that among adults, younger and older children, straightforward stimulus repetition plays a facilitating role in memory formation and learning (Bauer, 1997; Ihssen, Linden & Shapiro, 2010). Thus, repetition is one of the mechanisms that may have aided children's performance in the current place memory task. Although these studies investigated the repetition-memory link in general, and not specifically the link between repetition and spatial memory which the current study explored, it is plausible to explain the current findings in the light of the literature reviewed. Repetition seems to be a rather flexible concept that can be moulded to explain a variety of research findings within the domain of memory. However, the link between same-object delay (repetition) and improved place memory is subject to debate. Research has shown that repeated viewing of the object in the same location resulted in profound place learning (Lange-Küttner & Küttner, 2015). In the current study, children were initially presented with a grid containing an object in a place, followed by a filled delay task which was an empty expanse with the delay object (same or different) in a central position on the screen. Thus, in the context of this study, the same object was not presented in its original location, and it was larger in size. Therefore, one can conclude that repeated exposure of the same object should improve object rather than place memory because children's attention is being captured by the object, thus overshadowing the place it occupies. An answer to this riddle lies in that when children initially saw the object-in-place during the presentation phase, they presumably formed an object-place association. Thus it seems as though despite the nature of the delay task, the sole repetition of the object was enough to reinforce and facilitate the established object-place binding. On the other hand, a different object exemplar in the delay task destroys the object-place binding (dissociation).

Nonetheless, when the same model was run with a stepwise addition of the covariates, the effect of delay was no longer significant. This shows that the interference effect was somewhat dependent upon differences in age, intelligence and visual-motor integration skills. For example, in a study by Burgess and colleagues (2011), they found that brain activity on high-interference trials was strongly correlated with fluid intelligence and working memory span (Burgess, Gray, Conway & Braver, 2011).

When analysing reaction times, results showed that children's place recognition was slightly faster upon presentation of the same object in the delay, as opposed to a different-object exemplar for the technical and neutral objects, but not for items in the roleplay category. The phenomenon of repetition priming can serve as one of the explanations for this increased speed of place recognition. Repetition priming postulates that as the number of exposures to a particular stimulus increases, so does processing speed (Logan, 1990). This is accompanied by a decrease in neural activity (Grill-Spector, Henson & Martin, 2006). Repetition priming is functional with words, pictures and picture fragments (Russo, Nichelli, Gibertoni & Cornia, 1995). Furthermore, it seems as though the different object exemplar destroys the memory trace to some degree because the object-places association is disassociated by drawing attention to a different placeholder, resulting in comparatively slower place recognition.

As predicted, the analysis of place memory accuracy revealed that the effect of delay varied with group: Place memory of the clinical and control groups benefitted from the same-object delay in comparison to a different-object exemplar, but the difference was smaller in the ASD group. A significant comparison was noted between autistic children and respective MA controls when a different-object exemplar was viewed in the delay task: Children with ASD maintained better memory performance, indicating that they were less interfered by an object change producing a diminished interference effect in ASD children. One could reason this as autistic children having better control for interference. In a study conducted by Geurts and colleagues (2004), results showed that among children with high-functioning autism, interference control was not impaired (Geurts, Verte, Oosterlaan, Roeyers & Sergeant, 2004).

A significant interaction effect for reaction times between group and delay was absent altogether, showing that the slower speed of ASD children was not the reason for their diminished propensity for object interference. Another explanation could be that ASD children were *less bound* by a focus on meaningful entities, that is, the objects presented in the task, which may have led to decreased visual attention towards the delay object and thus maintenance of place memory accuracy. Furthermore, unlike previous research, ASD children may have used their good perceptual abilities to form categories. According to research in the field of object categorization, typically developing children possess a profound ability to recognise and classify objects (Mervis & Rosch, 1981). In contrast, the majority of research demonstrates the lack of object categorization in ASD children (Klinger & Dawson, 2001; Plaisted, 2001). However, one can reason that if there is strong categorization, a different exemplar has more power to break up the object-place association, leading to memory deterioration. A study by Johnson & Rakison (2006) found that object categorization in ASD children appeared to be driven by local (versus global) processing as reflected by their hyper-attention to parts of objects, enabling them to form rule-based categories. Likewise, in the current study, categories were potentially formed based on selective parts, for example, objects with wheels may have been classified as vehicles. On the other hand, typically developing children may have focused on the objects as a whole in order to successfully extract common characteristics across objects – a more difficult approach toward object categorization (McGregor & Bean, 2012). This may also explain why the respective MA controls were affected by interference to a greater degree.

When differences in age, intelligence and visual-motor integration skills were accounted for, the interaction effect of delay by group remained highly significant. This further confirmed the robust nature and eminent role of the interference effect on place memory accuracy, with lower object interference in children with ASD which occurred independently of the control variables.

Additionally, the predicted content by delay effect emerged showing that the same-object delay versus different-object exemplar benefitted the place memory accuracy of technical, roleplay and neutral objects, but this effect was more pronounced for technical toys as indicated by comparatively prolonged reaction times thereafter in the test trials. Therefore, it can be reasoned that the technical toy preference were acting like a place memory facilitator, whereas the human roleplay figures were interfering with children's place memory.

4.4. Children's Spatial Binding Strategies: Systematic versus Unsystematic Coders (Common Region Test, CRT)

In the current investigation exploring spatial memory in autistic, ADHD and typically developing children, children's spatial binding strategies were also considered, assessed via the Common Region Test (CRT). This was a basic measure as spatial binding strategies reflect the transition from better object to better place memory, or figurative topological to Euclidean space (Lange-Küttner, 2009; Newcombe & Huttenlocher, 2003; Piaget & Inhelder, 1956; Piaget, Inhelder & Szeminska, 1960). Hence, it would have been possible to directly test whether the interference effect would have its roots a disassociation of object-place binding. Although the predicted interaction effect between experimental group and the CRT was not directly implicated, a percentage analysis of the common region coding by group did however reveal that those children with special needs showed a significantly higher percentage of unsystematic binding than TD children. Hence, different to previous research which would encode object-place binding versus object-area binding, the CRT was analysed by pooling the systematic binding of object-place and object-area, and contrasting this with unsystematic binders that are so rare in typically developing samples of children that they are usually excluded from the analysis (Lange-Küttner, 2013).

With regards to the prevalence of unsystematic coding in children with ASD and ADHD, there is no straightforward explanation, paving the pathway to investigate this further in future studies. The Gestalt psychologist Palmer (1992) saw drawing common regions according to Gestalt principles such as proximity and similarity as second order Gestalt process, or in more historical terms, as apperception, that is perception based on cognitive concepts. Research has shown that not all ASD children have a talent for drawing (Eames & Cox, 1994), hence employing indirect performance-based measures of perceptual grouping that do not require participants to explicitly report the output of their grouping processes, such as, an eye tracking device may be useful in future studies to investigate this lack of cognitive control. For example, Falter and colleagues (2010) used an indirect measure of perception and found that children with ASD (versus neurotypicals) largely grouped by proximity, whereas grouping by similarity was absent to a great extent. These results suggest significant perceptual abnormalities in autistic children (Falter, Grant & Davis, 2010).

Results of the current study revealed a robust interaction of the CRT with content and the two types of delay when controlling for age, intelligence and visual-motor integration skills. This was somewhat expected as significant age differences between systematic and unsystematic coders were not found. A facilitating effect of the same-object delay versus a different-object exemplar was evident among systematic and unsystematic coders across all object categories, but the facilitation was more pronounced in systematic coders particularly for place memory of where exactly technical toys were located in the grid. This finding shows an increased benefit of the same-object delay among systemizers which may indicate that the sole repetition of the object, especially for objects in the technical toy category, reinforced the object-place association that systematic coders had established during the presentation phase. Thus these findings reflect that systemizers and non-systemizers may vary on how well they control the identity of exemplars, which influences place memory thereafter. Adding to this, the lower facilitating effect of repeated exposure in non-systemizers may well be a central core of a learning problem in both ASD and ADHD children. A particularly interesting finding was that unsystematic ASD coders were more affected by the different-object interference, which indicates a lack of cognitive control over object features, but there was no difference for ADHD children.

The interaction of content by delay by CRT was not only significant when place memory accuracy was analysed, but now also for reaction times. Interestingly, unlike the results of the accuracy analysis, among the ASD and ADHD systematic and unsystematic coders, the type of delay did not impact place memory reaction times for the technical, roleplay and neutral objects. However, reaction times of the systematic coders in the ASD group, in particular for the technical objects, did benefit more from the repetition compared to unsystematic coders. This may suggest that by directing attentional resources to the same placeholder, memory trace of the object-place binding formed by systematic coders is retained. In other words, this may act like a preventative measure against decay, potentially resulting in faster place recognition.

4.5. Limitations

Although the present study contains some insightful findings, the research does have a few limitations. Firstly, the diagnostic assessment tools used for the screening of ASD and ADHD were not included across all groups of participants. That is to say, they were only administered to the clinical groups and not the control groups per se. Thus, one can infer that children in the control groups may have developed either of the two conditions over time, in turn, serving as an explanatory factor for task performance. For this reason, it is vital that in future research, children in the clinical and control groups are screened for ASD and ADHD.

Another limitation of the current research is that children in the clinical groups were merely classified as having ASD or ADHD, but the severity of the condition was not taken into account. For example, differences in spatial memory task performance may be evident in children who are high-functioning on the autism spectrum versus low-functioning ASD children. This may also be applicable for children with “severe” symptoms of ADHD versus those with “milder” symptoms. Thus, future research can address this limitation by having “low” and “high” severity groups for children with ASD and ADHD in order to draw performance-based comparisons between the groups.

5. CONCLUSION

In the domain of visual-spatial memory, research has shown that spatial memory in autistic children was not impaired (Ozonoff and Strayer, 2001), while boys with ADHD showed a deficit when learning object locations (Reck, Hund & Landau, 2010). A lack of place learning in neurotypicals, especially younger children, usually occurs as a result of an object overshadowing the place it occupies (Lange-Kuettner, 2010b). Having said this, the first aim of the current study to show better spatial memory in autistic children was achieved albeit only when place memory performance of ASD children and respective MA controls was compared. The second aim to investigate the positive impact of the same-object delay via repetition versus the negative impact of a different-object exemplar was also supported by the findings of the study: Place memory accuracy and reaction times of all children largely benefitted from the same-object delay, showing the eminent and facilitating role of repetition in children’s spatial memory. The final aim to explore intense and circumscribed interests in this male dominated sample was reached. The reaction-time accuracy trade-off especially for the technical toys, clearly indicated children’s interest in this particular kind of toy. Thus, the notion of being technically minded and systematic was confounded by Baron-Cohen’s extreme male brain theory (Baron-Cohen, 2002, 2003). In the current study, approximately 75% of this mostly male sample were unsystematic coders, yet they displayed stronger preferences for technical toys such as vehicles, construction sets and lego. Therefore, being technically minded does not necessarily mean being systematic. Moreover, when children’s spatial binding strategies were considered, the intricate interplay between the content, delay and the CRT revealed that the CRT played an eminent role in children's place memory performance.

5.1. Future Directions

In future research, it may be interesting to test whether the spatial memory task used in the current study could also be applied to various clinical settings, for example, as an objective assessment tool in order to detect ASD symptoms. It will also be intriguing to use the present task in other clinical populations, such as children with Williams syndrome. Bernardino and colleagues (2012) found a central coherence processing of the task material among children with Williams syndrome. Thus, it would be interesting to compare the performances of ASD children who have local integration versus children with Williams syndrome who have global integration using the spatial memory task devised in the current study, shedding extra light on the cognitive characteristics of children in these two clinical populations.

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7. APPENDICES

Appendix A

Table of Stimuli (per object category)

Category	Object	Familiarity	Complexity
Cuddly Toys		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Playmobil		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Dolls		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Musical Instruments		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

School Items		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Sports Items		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Construction Sets (Metal)		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Construction Sets (Plastic)		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Lego		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Table continued on the next page

Vehicles		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A
		N/A	N/A

Appendix B

Consent Form

LONDON METROPOLITAN UNIVERSITY

15th October, 2016

Dear Parent,

Children's Location Memory

You all know that the academic success and development of your child depends also on his or her memory ability and learning capacity. I would like to ask your permission to work with your child on a study on visual-spatial memory. Young children's memory for locations is particularly lacking, whilst, on the other hand, their shape memory is quite good. I am trying to find out whether children have better place recognition for real-life rather than geometric objects.

Children will take part in a computer task of approximately 30 minutes, where they are asked to press a response key whenever they recognize a place they had seen previously. Usually children come out of the session very focused and ready to learn, also to the pleasure of the teachers! I have previously worked with children as a classroom assistant on a voluntary basis, and of course have a clean police record. My supervisor is Dr. Chris Lange-Küttner:

http://www.londonmet.ac.uk/faculties/faculty-of-life-sciences-and-computing/staff/prof-dr-chris-lange-kuettner/

I would be very grateful if you could sign the consent slip below and return it to the school at your earliest convenience.

Yours sincerely

Ridhi Kochhar, BSc. (Doctoral Candidate)

Dr Chris Lange-Küttner (Supervisor)
BPS Chartered Psychologist - BPS Associate Fellow

I herewith agree that my son/daughter (please delete accordingly) ……………………………………born on the …………………… Year ………is allowed to take part in the place memory task with Ms. Ridhi Kochhar. All data will be processed anonymously, as only age-specific group data will be used. My child has the right to withdraw at any time during the experiment.

…………………………………………………

Parent/Guardian signature

Appendix C

Table of Place Memory Accuracy and Reaction Time Mean Scores for the Ten Object Categories (*N*=117)

	Object Category				
	Construction Metal	Construction Plastic	Cuddly Toys	Musical Instruments	School Items
Place Memory Accuracy	62.0 (17.9)	62.7 (20.2)	64.1 (18.5)	58.1 (20.0)	59.7 (19.7)
Place Memory Reaction Times	24297 (18378)	29406 (18514)	7208 (9549)	6483 (5735)	8032 (7186)
	Object Category				
	Dolls	Lego	Playmobil	Vehicles	Sports Items
Place Memory Accuracy	55.0 (21.5)	58.3 (18.7)	61.4 (20.0)	68.2 (17.3)	65.5 (19.4)
Place Memory Reaction Times	6814 (4719)	23778 (19236)	7382 (6832)	27640 (14768)	6879 (4526)

Note. Accuracy in %, Reaction Times in milliseconds, SD in brackets.