Memory in Autism: Binding, Self and Brain

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Memory can be thought of as the capacity of an organism to utilise past experience in order to direct future behaviour. Such a capacity entails the registering and recording – the encoding - of that experience in such a way as to enable its subsequent retrieval. Retrieval can be either voluntary or involuntary and the resultant information may or may not form part of conscious awareness. The processes of encoding and retrieval are the result of a range of psychological processes and are in turn influenced by other factors both psychological and physiological. In this respect, study of the patterning of memory processes and the factors that influence their operation can give clues to the wider psychological functioning of the individual. It is in this last respect that the study of memory can enhance our understanding of people with autism spectrum disorder (ASD). ASD is not 'caused by' difficulties in memory, but the patterning of memory seen in individuals with ASD can provide clues to underlying cognitive and neuropsychological atypicalities as well as giving us a window onto their inner experiences of the world.

1.0 Preliminary Remarks

Any discussion of memory in ASD must first emphasise the heterogeneous nature of the conditions that comprise the autism spectrum. An important aspect of this diversity is the distinction between ASD with accompanying intellectual disability (often referred to as 'low-functioning ASD' or LFA) and ASD without it (often termed 'high-functioning ASD' or HFA). Intellectual disability in itself has consequences for memory (see Bray, Fletcher & Turner, 1997; Wyatt & Conners, 1998 for reviews), but we should be careful about assuming that these consequences operate similarly in individuals with co-occurring ASD. Nor should we assume that atypical memory patterns identified in individuals with HFA necessarily hold for those from the lower functioning parts of the spectrum. Similar arguments hold for the distinction between individuals who have good language and communication skills and those whose language capabilities are diminished or absent. At present, systematic investigations into how these dimensions affect memory in the context of ASD are thin on the ground, so readers need to be aware of potential difficulties of interpretation when drawing conclusions from research that has been limited to particular subgroups of people within the ASD population.

The same caveat applies to the topic of memory. Although at first it appears to be a straightforward process – the recollection of something that happened in the past – a moment's reflection throws up quite considerable complexity. 'Memory' is always *of* something and is assessed using particular procedures, often with a particular aim or purpose in mind. The writing of this chapter entails the recollection of words (verbal memory) and concepts (semantic memory) that have to be organised in a way that takes into account (however imperfectly) the minds of potential readers. Some of the information comes into the author's mind through a deliberate act of recollection (albeit prompted by the various cues that nudge authors to complete manuscripts on time) whilst other ideas are engendered by the reading of source texts. And all of these ideas are sorted and edited, accepted or rejected in the light of the overall aim of the exercise. Even this anecdotal scenario highlights the complexities that begin to emerge when considering where to draw boundaries for the concept of 'memory'. We need to be clear about the kinds of material that are being remembered, whether the memory involves unsupported recollection, prompted recollection, or simply recognition that we had encountered something previously. We also need to decide whether the remembered material was learned very recently or some time (maybe even years) ago. The topics of recollection, prompting or recognition have engendered some of the principal test measures used in laboratory and clinical studies of memory. Recollection is usually tested by *free recall*, in which participants study lists of words and then recall as many as they can in any order. The prompt here is minimal, usually involving a request from the experimenter to recall the words just studied. *Cued recall* provides more concrete and specific hints to aid recall. These hints may be phonological (e.g., words that rhyme with...; words that begin with...) or semantic (e.g., there were flowers, items of furniture etc.) in nature. Recognition involves studying long lists of items and then presenting these again, interspersed with non-studied items, asking the participant to indicate whether or not they had seen the item at study. Recognition may also be tested by presenting participants with a studied and a new word and asking them to indicate which they had seen before.

In parallel with material and procedural issues is the question of how we conceptualise what is going on in the brain and the mind during the operation of memory. New information must be encoded, which implies some kind of storage system, or a system that marks already-stored information in a way that links it to the study episode. Subsequent retrieval implies its own system or set of processes (for a fuller exposition of these topics, see Gardiner, 2008). Some theorists argue that memory can be divided into two distinct sets of processes, those that operate over the very short term (e.g., working memory, Baddeley & Hitch, 1974), and which are distinct from the processes that subtend long-term memory. Others, e.g. Bjork and Whiten (1974) and Crowder (1976) argue for an undivided memory system that may have particular characteristics when retrieval happens very soon after encoding. Advocates of both positions generally argue that memory (or long-term memory, in the case of advocates of multi-store models) can be divided into *procedural* and *declarative* memory systems, and that the latter can be further subdivided. For reasons of space, our discussion here will be limited to declarative memory in ASD. More detail on short-term and working memory in ASD can be found in Poirier and Martin (2008) and on procedural and implicit memory in Bowler, Matthews and Gardiner (1997), Gardiner, Bowler and Grice (2003), Mostofsky, Goldberg, Landa & Denckla (2000), Roediger and McDermott (1993) and Schacter and Tulving (1994).

Declarative memory is memory that is generally accessible to conscious awareness (Eichenbaum, 1999), different kinds of which are used by many theorists to delineate separate memory sub-systems and processes. Tulving (2001) posits several systems, each associated with a characteristic type of conscious awareness. The first of these systems is the *semantic memory system,* which is one's store of general knowledge or what Tulving calls 'timeless facts', the recall of which is accompanied by *noetic conscious awareness*. The second is the *episodic memory system*, which comprises recollection of personally-experienced events and involves the self engaging in mental time travel to re-experience the spatio-temporal context of the recollected episode. It is this experience of the self re-experiencing the past that he terms *autonoetic conscious awareness* and regards as being the hallmark of episodic memory. To a similar end, Jacoby (1991) contrasts *familiarity*, a non-effortful process and *recollection,* which involves active, conscious control by the participant. On this view, the quality of the conscious recollective experience depends on the relative contributions of familiarity and recollection to a particular memory. Cutting across these different systems and processes are considerations of the depth of processing (Craik & Lockhart, 1972) implied by different kinds of material and brought about by different memory tasks. For example, focussing on phonological aspects of words is thought of as entailing shallower levels of processing than does working out meaningful relations among them. All these different theoretical positions are tested experimentally using manipulations of the procedures outlined earlier. It is important to bear in mind that the results of a given experiment can often be interpreted in the light of different theoretical perspectives.

2.0 Empirical Findings

2.1 Standard experimental procedures.

Amongst the earliest studies of memory in ASD were ones concerned with memory span, a classic measure of short-term memory, which is determined by the number of items that a participant can correctly recall in the order in which they were presented. Initial reports showed that individuals with ASD exhibited relatively undiminished performance on such tasks by comparison with mental-age matched participants without ASD (Boucher, 1978; Hermelin & O'Connor, 1967). However, as Poirier and Martin (2008) observe, these early studies are compromised by the fact that groups were often matched on psychometric measures of digit span, which equates groups on their ability to recall the order of a series of numbers. When matching was based on non-span measures and when more demanding measures of span were utilised, Martin, Poirier, Bowler et al. (2006) found marginally diminished span in adults with HFA. More specifically, even though the absolute numbers of items recalled was undiminished, there was a significantly higher number of order errors in the recall of the HFA participants. These findings show that although the maximum number of items that individuals with ASD can recall is not different from that recalled by typical individuals, they have difficulties in recalling the precise order of the items, at least after a single exposure.

Free recall of longer lists of words – supra-span lists – without the requirement to preserve the order of the studied words has a number of characteristic features in typical individuals. The first few and the last few items in a list are more likely to be recalled than the middle items, yielding the classic *serial position curve* in free recall (Murdock, 1962). Recall of the last few items – the recency effect – is thought, by advocates of multi-store theories, to reflect the contents of a short-term store, whereas recall of the first few items – the primacy effect – is thought to result from processing of information into long-term memory. Another characteristic of supra-span list recall is that typical individuals tend to cluster (i.e. recall in sequence) items that are drawn from the same semantic category (Bousfield, 1953), and this clustering usually yields higher overall recall than for uncategorised lists. If the same list is presented repeatedly over several trials, then recall on each trial increases (*free recall learning*), and if the list is uncategorised, then participants will typically impose their own *subjective organisation* on the material, irrespective of the organisation of the studied list (Tulving, 1962). Assessments of phenomena such as these in ASD have yielded a characteristic pattern of observations.

Free recall of uncategorised material in individuals with ASD is usually undiminished (Bowler et al., 1997; Minshew & Goldstein, 1993; 2001; Tager-Flusberg, 1991) unless there is concomitant intellectual disability (see Boucher & Warrington, 1976; Boucher & Lewis, 1989). In terms of the classic serial position effect, individuals with LFA tend to show diminished primacy and enhanced recency effects (Boucher, 1979; 1981; O'Connor & Hermelin, 1967; Renner, Klinger & Klinger, 2000) whereas HFA individuals generally show typical serial position effects (Bowler, Gardiner, Grice & Saavalainen, 2000b; Toichi & Kamio, 2002). The latter finding, however, needs to be interpreted with some caution since a recent study by Bowler, Limoges and Mottron (under review) showed that the primacy effect of HFA participants shows a slower improvement over successive trials than that of typical individuals. This raises the possibility that the primacy effect observed on a single trial, although superficially similar between typical and HFA participants, may be mediated by qualitatively different processes.

The idea that memory operates in a qualitatively different manner in ASD and typical individuals is also evident in other memory phenomena. For instance, on later trials of multi-trial list learning, adults with HFA show slower rates of learning (Bennetto, Pennington & Rogers, 1996; Bowler, Gaigg & Gardiner, 2008a). Diminished learning is often a sign that participants fail to subjectively organise material for effective recall but surprisingly, individuals with ASD engage in such organisation to a similar extent as do typical participants (Bowler et al., 2008a). Individuals with ASD do, however, seem to engage in qualitatively different forms of subjective organisation. More specifically, whilst typical participants tend to converge in the way in which they organise a repeatedly presented list of words during their recall attempts, participants with ASD do not, indicating that their subjective organisation follows a rather idiosyncratic pattern. Differences in how memory operates in typical and ASD individuals are even more obvious when the to-be-remembered material is semantically interrelated. Typical individuals consistently exhibit a memory advantage for more meaningful information but in ASD this phenomenon seems to depend on the nature of the task. Failure to use semantic aspects of study lists to aid free recall has long been known to be a feature of memory in LFA and HFA (Bowler et al., 2000b; Bowler et al., 1997; Hermelin & O'Connor, 1970; Tager-Flusberg, 1991; but see Leekam & Lopez, 2003). Moreover, individuals from all parts of the autism spectrum are less likely to cluster semantically related items together in recall (Hermelin & O'Connor, 1967; Bowler, Gaigg & Gardiner, under review b). When category-cued recall or recognition procedures are employed, however, individuals with ASD often exhibit a relatively typical memory advantage for semantically interrelated materials (Boucher & Warrington, 1976; Bowler, Gaigg & Gardiner, 2008b; Mottron, Morasse & Belleville, 2001, Tager-Flusberg, 1991; Toichi & Kamio, 2002). These, more supported test procedures generally seem to prove less difficult for individuals with ASD (e.g., Bennetto et al., 1996; Bowler et al., 1997; Gardiner et al., 2003; Tager-Flusberg, 1991), suggesting that whatever processes are involved in free recall situations pose a particular difficulty for them. Individuals with ASD are, however, susceptible to associatively-induced illusions using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) regardless of whether recognition or free recall procedures are employed. During the DRM paradigm, participants study a series of strong semantic associates of a non-studied word (e.g., *bed, snooze, blanket, pillow, night…* all of which are strong associates of *sleep*), which often leads them to falsely recall or recognise the non-studied associate during a test phase. Two out of three studies (Bowler et al., 2000b; Hillier, Campbell, Kiellor et al., 2007) found that adults with HFA were as likely as typical participants to falsely recognise the non-studied associate and in the Bowler et al. (2000b) study the authors also failed to find significant group differences in a free recall test. The third study (Beversdorf, Smith, Crucian et al., 2000), using a slightly different method from the standard DRM paradigm reported increased discrimination of non-studied items in adults with ASD as did Hillier et al. (2007) when pictorial stimuli were used.

The final source of evidence, which suggests that memory operates differently in ASD, stems from a series of recent studies that have investigated whether individuals with ASD, like typical participants, remember emotionally significant information better than emotionally neutral information (see Reisberg & Hertel, 2004; Uttl, Ohta & Siegenthaler, 2006 for a collection of reviews). The first study to investigate this phenomenon in ASD (Beversdorf, Anderson, Manning et al., 1998) asked adults with and without ASD to try to remember a series of emotionally charged and neutral statements (e.g., 'He talks about death' vs. 'He is talking with his roommate') for a subsequent free recall test. The results showed that only the typical comparison group recalled the emotionally charged statements significantly better than the neutral ones despite the fact that groups did not differ in terms of their recall of sentences and paragraphs that varied in terms of their syntactic and conceptual coherence. Recent studies have extended this finding. In one of these, Gaigg & Bowler (2008) presented participants with a list of words containing emotionally charged and neutral words and asked them to rate how emotionally intense they felt about them. During study, skin conductance responses, which index to the extent to which participants are physiologically stimulated by the study material, were also measured. After participants had seen all the words, their free recall was tested at three points in time – immediately after they had seen the words, again after an hour and once more after at least one day. The findings showed that whilst groups did not differ in terms of their ratings of the words, their skin conductance responses to the words or their free recall performance on the immediate test, forgetting rates of emotional words over time were different in the ASD group. In a second experiment, Gaigg & Bowler (under review) employed a variant of the DRM illusion task developed by Pesta, Murphy and Sanders (2001) in order to determine to the extent to which it would be possible to induce false memories of emotionally charged words in individuals with ASD. Unlike typical participants who were far less likely to falsely recognise emotionally charged as compared to neutral words, those with ASD falsely recognised emotional and neutral words at roughly the same frequency. Only one study, to date, has failed to demonstrate differences between ASD and typical participants in their memories for emotionally charged words and interestingly this study employed a simple recognition test procedure (South, Ozonoff, Suchy et al., 2008), which generally pose few difficulties for individuals with ASD (Barth, Fein & Waterhouse, 1995; Bennetto et al, 1996; Bowler et al, 2000a,b; Bowler, Gardiner & Gaigg, 2007; Minshew, Johnson & Luna, 2001, but see Bowler, Gardiner & Berthollier, 2004)[1].

The findings outlined above show that the memory difficulties experienced by individuals with ASD are relatively subtle, and are present on tasks where minimal clues are given for recall and where information has to be manipulated or processed in some way. Before the broader implications of these observations are discussed, we need to present a further, and rather paradoxical set of findings centred on the fact that relatively spared recognition memory in ASD hides a subtle but persistent difficulty in episodic memory.

2.2 Episodic Memory

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[1] Individuals with LFA sometimes do exhibit difficulties on tests of recognition (Ameli, Courchesne & Lincoln, 1988; Barth et al, 1995; Summers & Craik, 1994) although this seems to depend on the precise nature of the recognition procedure used. What is needed to settle this question is a systematic evaluation of the effects of procedural and participant characteristics on recognition memory.

Despite recognition being an aspect of memory that poses few difficulties, at least for individuals with HFA, recent research has shown that this spared capacity conceals an important difficulty with episodic memory. One of the hallmarks of human memory is the ability to re-experience oneself at the heart of the spatio-temporal context of a previously experienced episode. The ability to do this involves an awareness of self that is continuous through past, present and future, as well as an ability to recollect not only that a particular event took place but also the context in which it happened. Some of the research on memory in ASD discussed above is consistent with a prediction that individuals on the autism spectrum might have atypicalities of episodic memory. Their relatively greater difficulties on recall-based compared to recognition-based tasks points to episodic difficulties. In addition, their diminished recall of incidentally-encoded context (Bennetto et al, 1996; Bowler et al, 2004, Bowler et al., 2008b) – sometimes referred to as source memory - constitutes another strand of evidence and the presence of frontal lobe-related executive function difficulties in ASD (see Hill, 2004a,b) together with the finding of episodic memory difficulties in frontal lobe patients (Wheeler & Stuss, 2003) is a third. More indirect support comes from a theoretical perspective of Perner and colleagues (see Perner, 2001), who argue that the cardinal characteristic of episodic memory – the re-experiencing of the self at the heart of a personally-experienced episode - depends on the ability to represent oneself as an experiencer of events, and to evoke that representation in memory. This *metarepresentational ability*[2] develops during the child's fourth and fifth years and according to Perner, also underlies the ability to understand the behavioural consequences of false belief in others. Difficulties with false belief understanding are seen in at least some manifestations of ASD (Baron-Cohen, Leslie & Frith, 1985, but see Bowler, 2007, Chapters 2 & 3), and on Perner's

[2] What is described here is Perner's conception of the term 'metarepresentation' (see Perner, 1991), which differs radically from that used by Leslie (e.g. Leslie, 1987), and which is also used in the context of 'theory of mind' in ASD.

arguments they should, as a consequence, experience diminished episodic remembering.

A widely-used test of episodic memory is the ‘Remember/Know’ (R/K) procedure developed by Tulving (1985). Participants are asked to study a supra-span list of words for a later memory test. At test, they are presented with single words, half of which comprise the earlier-studied items, and are asked whether or not they had seen the word at study. If they answer ‘yes’, they are then asked to make either a ‘remember’ (R) judgment, where they can clearly recollect the episode of having studied the word, or a ‘know’ (K) judgment, where they simply know that they studied the item without any recollection of details of the study episode. Bowler, Gardiner & Grice (2000a) utilised this procedure with adults with ASD and normal intelligence and found that the ASD group showed diminished R but not K responses by comparison with typical individuals matched on age and verbal IQ. In order to assess whether the R responses that the ASD participants did produce were the result of similar underlying processing to that of the comparison group, Bowler et al. (2000a) included in the study list words that are encountered in English either frequently or infrequently. Low-frequency words typically yield more R responses in the R/K paradigm, and a similar pattern in the ASD group would suggest that although diminished in quantity, their R responses would be similar in quality to those of typical individuals. This is what Bowler et al. found, and in a further series of studies that manipulated other factors known to affect levels of R and K responses in typical individuals, Bowler et al. (2007) found that adults with ASD and normal IQ responded to these manipulations in a similar manner to matched typical comparison participants. Dividing attention at study diminished R but left K responding unaffected, emphasising a perceptual set at study by asking participants to look out for blurred letters increased K responses but left R responses unaffected, and increasing number of study episodes increased R but not K responses.

The picture that emerges from the studies of Bowler et al. (2000a, 2007) is that individuals with ASD show quantitatively diminished but qualitatively similar experiences of episodic recollection. What remains to be established is whether this is the result of problems in re-constructing the spatio-temporal aspects of the recollected episode or in imagining the self at the heart of such recollection or of difficulties in both these factors. We will now discuss the research relating to both these possibilities as well as on the related issue of the ordering of elements of experience in time.

2.3 Re-creating the spatio-temporal context of an episode

Individual episodes are characterised by the co-occurrence of elements of experience (e.g., meeting a particular friend at a particular time of day in a particular place etc.) that may form part of other, distinct episodes. What defines an individual episode is the combination of attributes that are unique to it. For an episode to be successfully retrieved, its elements need to be marked in such a way as to enable their subsequent retrieval as a bound unit. Bowler, Gaigg and Gardiner (under review, a) showed that this *relational binding* capacity is diminished in individuals with ASD. They replicated a study of Chalfonte and Johnson (1996) who asked older and younger typical adults to study sets of objects located in the cells of a grid. The objects were presented in non-canonical colours (e.g. a blue banana or a pink leaf). Participants' recognition of individual features (location, item, colour) and combinations of these features (item + location, item + colour) were then tested. Whereas older participants showed undiminished recognition of features, they were significantly poorer on recognition of combinations. Bowler et al. (under review, a) found similar intact feature and diminished combination recognition in a group of HFA adults, demonstrating that they too had difficulties in recognising episodically-defined bindings of elements of experience. This finding was all the more surprising in that it demonstrated a binding difficulty on a memory task – recognition – that does not usually pose problems for individuals with ASD.

It can be argued that an intact ability to re-construct the combinations of features unique to an episode and the development of an accurate sense of the temporal order of events are intimately and necessarily related. It follows from this that difficulties with the relational binding needed to recollect an episode should be accompanied by difficulties in temporal aspects of memory. There are several strands of evidence from the ASD literature that support the conjecture that this is the case in ASD. Bennetto et al. (1996) demonstrated diminished performance on an adaptation of the Corsi task in adolescents with ASD. This task presents participants with sequences of concrete words or line drawings. From time to time, a yellow card accompanied by a pair of previously-presented items is presented and participants have to decide which of the two items had been presented more recently. Diminished performance was also reported in a serial order recall task in which Martin et al., (2006) asked adults with ASD to recall lists of digits that are close to their memory span. Although the number of items correctly recalled was similar to that of comparison participants, the ASD group made more order errors in recall, suggesting that they have difficulty recalling which items preceded and succeeded each recalled item. Theorists such as Brown, Neath & Chater (2007) argue that sensitivity to such micro-contextual detail underlies successful serial recall, and its diminution in ASD further reinforces the idea that this population experiences particular difficulty in the accurate recall of the context of remembered material. The occurrence of the phenomenon in serial recall further supports the idea that accurate recall of context is needed for accurate temporal memory.

Individuals with ASD have also been shown to have difficulties in reconstructing the order of occurrence of a set of items. Gaigg, Bowler & Gardiner (submitted) asked adults with ASD and matched typical comparison participants to re-order alphabetically-presented lists of seven historical figures either into their actual chronological order or into a pseudo-random order that had been studied just beforehand. Whereas performance on the first task was comparable between the two groups, the ASD participants were significantly worse on the second task, indicating that they had particular difficulty in encoding an episodically determined ordering of the studied material. Difficulty in temporally ordering recall of material is also reflected in poor performance on narrative tasks. Reported difficulties include poor narrative organisation (Losh & Capps, 2003), diminished story recall (Williams, Goldstein & Minshew, 2006) and reduced use of temporal referential devices in narrative (Colle, Baron-Cohen, Wheelwright & van der Lely, 2008). In a series of tests of diachronic thinking (the ability to reason about the unfolding of events over time), Boucher, Pons, Lind and Williams (2007) found poorer performance in children with ASD compared to matched typical children.

All these findings reinforce the long-held view (see O'Connor & Hermelin, 1978; Boucher, 2001) that individuals with ASD experience difficulties with remembering the temporal ordering of experience. The argument is made here that this difficulty is a consequence of difficulties with the binding together of elements of experience in episodic memory and which may have repercussions for the development of self-awareness. In a later section, we outline how such binding difficulties might have wider application to difficulties with semantic organisation as well as to episodic memory. First, we need to consider the other key aspect of episodic memory: the role of self awareness.

2.4 The Self and Memory in ASD.

Wheeler, Stuss and Tulving (1997, p.334) suggest that, "only through the sophisticated representation of self can an individual autonoetically recollect personal events from the past." If this approach is correct then self-awareness is an essential component of episodic memory. Studies of mirror self-recognition (e.g., Ferrari & Matthews, 1983), delayed video self-recognition (Lind & Bowler, under review, a) and action-monitoring (e.g., Williams & Happé, in press) suggest that individuals with ASD have intact awareness of their bodily selves and physical agency. However, individuals with ASD appear to have diminished introspective awareness of their own mental (e.g., Philips, Baron-Cohen, & Rutter, 1998) and emotional states (Ben Shalom, Mostofsky, Hazlett et al., 2006; Gaigg & Bowler, 2008; Hill, Berthoz, & Frith, 2004). Such a diminution of self-awareness may contribute to the episodic memory difficulties experienced by individuals with ASD.

Some researchers have suggested that ASD may entail specific difficulties in *personal* or *autobiographical* episodic memory (Powell & Jordan, 1993; Crane & Goddard, 2008). Consistent with this position, studies of autobiographical memory have indicated that whilst semantic autobiographical knowledge (e.g., knowledge of one's date of birth) is intact amongst adults with ASD, episodic autobiographical memory (e.g., memory for one's first day at secondary school) is diminished (Crane & Goddard, 2008; Goddard et al., 2006; Klein, Chan, & Loftus, 1999). Moreover, evidence from a study by Lee and Hobson (1998) suggests that the verbal accounts of autobiographical events of people with ASD, in general, cannot be assumed to reflect episodic autonoetic remembering. As part of a study of self-understanding, Lee and Hobson asked children, "Do you change from year to year?" In response to this question and subsequent probes, they found that 75% of participants with ASD, but no comparison participant, recounted events from babyhood. The quality of these verbal accounts did not differ from the quality of their other reported memories. The observation for the comparison participants is entirely in line with the position of 'infantile amnesia' advocated by most theories on typical memory development in children (see Bauer, 2006 for review). However, the observation for the ASD participants is not – in typical development, memories of events occurring prior to the age of approximately 3 to 4 years are very rarely retained in later childhood or adulthood. It is the fact that these "recollections" of babyhood did not qualitatively differ from their other "recollections" that may lead us to question whether any of their verbally described autobiographical memories were episodic in nature. These data appear to be consistent with the hypothesis that autobiographical episodic memory is diminished in ASD.

It has also been suggested that there may be ASD-specific impairments in memory for experiences directly involving the self (Hare, Mellor, & Azmi, 2007). Typically developing individuals from 6 years of age upwards demonstrate superior memory for self-performed tasks than other-person-performed tasks (e.g., Engelkamp, 1998; Roberts & Blades, 1998). This memory advantage, which is associated with being a participating agent as opposed to an observer, is known as the *enactment effect*. One account of the enactment effect is that memories of self-performed actions are more salient because they involve an additional motoric component. The effect, therefore, depends on the capacity for action-monitoring, which involves distinguishing between internally and externally caused changes in perceptual experience.

If ASD entails impairments in memory for experiences directly involving the self (Hare et al., 2007), one might predict that individuals with ASD should show a reduced or absent enactment effect. Indeed, some studies have either failed to show a significant enactment effect amongst participants with ASD (Farrant, Blades & Boucher, 1998; Hare et al., 2007), or have found an "observer effect", where participants with ASD demonstrated significantly better memory for another person's actions than for their own (Millward, Powell, Messer, & Jordan, 2000; Russell & Jarrold, 1999). However, two more recent studies have indicated that children with ASD show the enactment effect to the same extent as comparison children (Lind & Bowler, under review; Williams & Happé, in press).

Lind and Bowler's (under review) study of memory for self and other in ASD included more than double the number of participants (n = 53) used in any previous study (maximum n employed = 22). Their results may, therefore, be considered more representative. They devised a task which assessed recognition and self-other source memory. It was found that children with ASD showed significantly diminished source memory but undiminished recognition memory, relative to age- and ability-equated comparison children. Both children with ASD and comparison children showed an enactment effect, demonstrating significantly better recognition (large effect size) and source memory (medium effect size) for self-performed actions than other-person-performed actions. Despite past speculations that ASD might involve action-monitoring difficulties (e.g., Russell, 1996), subsequent research has demonstrated that this is unlikely to be the case (e.g., Williams & Happé, in press). Thus, it is perhaps unsurprising that children with ASD should show the enactment effect to the same extent as children without ASD.

Taken together, the evidence suggests that individuals with ASD experience difficulties with episodic memory *per se* - their difficulties are not isolated to *personal* or *autobiographical* episodic memory. However, this conclusion does not undermine the hypothesis that diminished self-awareness may contribute to episodic memory difficulties in ASD. It is likely that the ability to introspect on one's own mental states and to represent oneself as an entity that is extended in time is intimately related to episodic memory in general. Mentally re-experiencing any event – whether it is central to one's autobiographical history or otherwise – is likely to depend on such a sophisticated level of self-awareness. It is also possible that a sophisticated level of self-awareness depends on the ability to re-construct a sequence of episodes, the ordering of which depends on the accurate binding of episode-relevant clusters of elements of experience.

3.0 Wider Conceptual Themes.

The findings reviewed so far show relatively subtle memory difficulties that tend to centre on manipulation of information in memory rather than the memory for the information itself. These difficulties tend to have greater repercussions on measures that provide less support at test (e.g. free recall) than those that do not (e.g. recognition). From the perspective of dual-store or working memory models, the findings both of span studies and on serial position effects show that difficulties seem to lie less with any of the memory storage systems and more with the central executive of the working memory system (Baddeley 1986). Research also shows that there is particular difficulty in manipulating material in ways that enable the detail of past episodes to be re-constructed and that this interacts in some way with the 'mental time travel' that is needed for the operation of episodic recollection. And finally, the way in which memory is modulated by emotional factors operates atypically in ASD. In the following two sections, we will tease out some implications of these patterns of memory performance in an attempt to elucidate underlying processes that give rise to them. In a final section, we attempt to reconcile the empirical findings and theoretical speculations with a brain-based account.

3.1 Task Support

The research reviewed so far paints a picture of difficulties in recalling material, especially when recall entails some effort, such as elucidating and manipulating semantic aspects of the material or when recall has to be enhanced over repeated trials. By contrast, fewer difficulties are seen on tasks that provide more explicit support for retrieval, such as cued recall or recognition. This particular pattern was first noted by Boucher (Boucher, 1981; Boucher & Warrington, 1976) and again by Bowler et al. (1997) and led to the coining of the term *Task Support Hypothesis* (TSH) by Bowler et al. (2004). As well as describing the patterning of memory performance across tasks in ASD, the TSH has proved to have considerable heuristic value. It has highlighted a parallel between the patterning of memory performance seen in typical ageing (Craik & Anderson, 1999) and in frontal lobe damage (Schacter, 1987) and has helped to account for some apparently contradictory findings in the literature. For example, Bennetto et al. (1996) reported diminished source memory in adolescents with ASD, whereas Farrant et al. (1998) reported no difficulties in a younger, lower-functioning group. The first study defined source memory as the number of intrusions from an earlier-learned list into the recall of a later list, whereas the second defined it in terms of children's capacity to indicate whether they themselves or the experimenter had spoken a given word at study. Bowler et al. (2004) noticed that the first study involved an unsupported measure of source, whereas the second involved a supported test. On this basis, they devised two experiments in which HFA participants studied lists of words, which were either presented in one of four ways, or which the participant had to manipulate in one of four ways. At test, participants were given a yes/no recognition test and if they said 'yes' to a test word, were asked either to select the means of presentation or the kind of action from a list on the screen (supported test), or else simply to recall what it was (unsupported test). The results showed no HFA-comparison group difference on the supported test, but diminished performance in the ASD group on the unsupported test, thus extending to source memory the view that memory is particularly difficult for people with ASD when unsupported test procedures are used. A similar role for task support on memory for incidentally-encoded context was demonstrated by Bowler et al., (2008b). Participants with and without HFA studied a series of words on a screen. Each word was surrounded by a red rectangle, outside of which was another word that was either strongly or not at all associated with the word inside the frame. Participants were told to ignore the words outside the frame. Later testing used either a free recall or a four-option forced-choice procedure. In each case, participants were told to try to remember all words they had seen, whether inside or outside the frame. The results showed that associative relatedness between studied and incidentally-encoded words (those inside and outside the frame respectively) benefitted both groups' recognition but enhanced recall only in the typical group. Both these studies show that supported test procedures yield better memory than unsupported procedures for incidentally-encoded context as well as for incidentally-encoded item-context relations.

The TSH paints a picture of memory in ASD as being heavily influenced by the here-and-now. This would suggest less 'top-down' processing in which stored representations influence how incoming information is interpreted. The diminished use of semantic structure to aid recall described earlier, together with demonstrations of diminished top-down processing in visual perception (see Mitchell & Ropar, 2004 for review) provide converging evidence that individuals with ASD store information in ways that are less likely to influence the processing of later, new information. The question now arises of why stored information is less effective in modulating the processing of incoming information in ASD, thus yielding a behavioural reliance on task support.

3.2 Relational Processing Difficulties

Research on episodic memory in people with ASD strongly supports the idea that they experience difficulty in processing relations among elements of experience. Understanding this difficulty can be enhanced by a more detailed consideration of the parallel problem that they sometimes experience in utilising semantic relations among studied items in order to enhance their recall. As we have already seen, failure to use meaning to aid recall has long been known to be a characteristic of ASD (Bowler et al, 1997; 2000a; Hermelin & O'Connor, 1970; Smith, Gardiner & Bowler, 2007; Tager-Flusberg, 1991 but see Leekam & Lopez, 2003), yet performance on other tasks that rely on semantic processing seems relatively unimpaired. We have already mentioned that people with ASD perform as well as typical individuals on category-cued recall (Boucher & Warrington, 1976; Mottron et al., 2001, Tager-Flusberg, 1991; Toichi & Kamio, 2002), suggesting some ability to use meaningfulness to aid memory. One way to account for these apparently contradictory findings is to invoke the TSH, since semantic relatedness appears to be a problem only when less supported test procedures are used. This argument is further supported by Bowler et al.'s (2008b) observation that whereas relatedness between studied words and context enhanced recognition and recall of studied items for typical individuals, it enhanced only recognition for ASD adults of normal IQ. Thus, we can see that the requirement to engage in semantic processing is more likely to adversely affect memory in individuals with ASD when unsupported task procedures are utilised.

This account is problematic in that it merely describes and does not explain *why* support is needed for semantic processing. It may simply be that the two phenomena are opposite sides of the same coin. One way to go beyond description is to invoke the distinction between *item-specific processing* and *relational processing*. Item-specific processing refers to a tendency to focus on individual items of information without reference to relations among them. Item-specific processing has been shown to contribute heavily to performance on tests of recognition (Anderson & Bower, 1972), on which individuals with ASD perform well. Their pattern of performance on depth-of-processing tasks (for example, where memory is enhanced if studied words have to be rated on deeper, often semantic aspects such as asking if it is a fruit rather than shallower features such as number of vowels) also suggests that they perform as well as comparison participants on deeper processing tasks and better on shallower processing tasks (Toichi & Kamio, 2002; 2008). The pattern of performance on the two processing levels suggests that individuals with ASD, unlike typical individuals, process words in the two conditions in a similar manner, one, moreover, at which they are highly proficient. It can be argued that this is likely to be an item-specific strategy, since it is difficult to see how shallow tasks could be accomplished by recourse to a relational strategy. More direct evidence on this question comes from a study by Gaigg, Gardiner & Bowler (2008c), who adopted a procedure developed by Hunt and Seta (1984) in which participants studied lists of words drawn from a number of different categories. Some categories were represented by only 2 exemplars, whereas others had 4, 8, 12 or 16. Whereas typical comparison participants recalled similar proportions of items from small as from large categories, adults with ASD recalled far fewer items from the smaller categories. Following Hunt & Seta (1984), Gaigg et al. argue that this is because identification of exemplars from smaller categories requires alertness to semantic relations among items. By contrast, ability to recall individual exemplars from large (i.e. frequently-represented) categories requires alertness to the unique features of each item. Moreover, Gaigg et al. found that whereas provision of a relational orienting task (sorting words into categories) enhanced the recall of the typical individuals, it did so for the ASD group to a lesser extent. Provision of an item-specific orienting task (rating word pleasantness) had similar effects on recall for both groups. Gaigg et al.'s findings are consistent with the view that whereas typical individuals have both relational and item-specific processing at their disposal when performing memory tasks, individuals with ASD are dependent to a greater extent on item-specific processing alone. This would explain not only the patterning of performance across tasks described at the start of this chapter but also the greater reliance on task support seen in ASD. A focus on individual items of information diminishes relational semantic information available to aid recall, and diminishes the amount of related contextual information that can be drawn on to re-create episodic recollections and their associated self-involved states of conscious awareness.

Two caveats are in order concerning the foregoing account. The first is that we should be wary in attributing an *absence* of relational processing in ASD. It may simply be the case that the balance between the two types of processing is different in this population. The second, more serious concern, is that there exist tasks that appear to involve relational processing (deeper levels-of-processing manipulations, susceptibility to associatively-generated memory illusions), that are, nevertheless relatively unproblematic for individuals with ASD. To avoid inconvenient, *post-hoc* attempts to accommodate these findings, we need a more principled theoretical account of the relational processing difficulties seen in ASD.

A speculative, yet empirically testable way to explain why relational processing difficulties are more likely to be seen only on some tasks but not on others is through a more detailed analysis of the demands that different memory tasks place on participants. When participants engage in free recall of a categorised list, in order for them to become aware of the categorical nature of the studied items, they have to consider each in relation to other words on the list (e.g. *cat with dog* or *apple*) and then to relate this comparison to higher-order category labels (*animal, fruit*). Contrast this with the situation in a classic memory illusions experiment (e.g. Bowler et al., 2000b) described in an earlier section. Here, when participants study associates of a non-studied word, they are highly likely to remember the non-studied associate because it is activated by each of the studied items (e.g., bed-*sleep,* night-*sleep,* pillow-*sleep,…)*. The operations required of the participant in the case of recall of the categorised list involve three-way processing between pairs of words and their hierarchical categories, whereas the illusory memories require only two-way processing between a studied item and its associate. On this analysis, what seems to pose particular difficulty for individuals with ASD is the complexity of the memory task. Task complexity in relation to typical children's development has been explored in detail by Halford (1992) who argues that cognitive development proceeds from a stage where individual items are processed in isolation (*unary relations*) followed by the processing of items in a pair-wise fashion (*binary relations*) and finally by the ability to process three-way or *ternary* relations among triplets of items.

Although the above analysis of memory in ASD is consistent with Halford's (1992) relational complexity account, it needs further confirmation by more systematic, hypothesis led investigations. Nevertheless, it is corroborated by evidence from other areas of psychological functioning in ASD. Andrews, Halford, Bunch et al. (2003) report that the standard 'Sally-Anne' false belief task on which children with ASD are characteristically delayed (Baron-Cohen et al., 1985) correlates highly with performance on tasks of ternary relational processing, and Bowler, Briskman, Gurvidi & Fornells-Ambrojo (2005) report similar levels of delay in children with ASD on a non-social task of complex reasoning and the Sally Anne task. Both tasks are consistent with a ternary processing analysis, suggesting that it is the processing complexity and not the mental state nature of the Sally-Anne task that poses particular difficulty for the children with ASD.

Difficulty in processing three-way relations is also a theme that recurs in two of the major theoretical accounts of the development of ASD. Early in development, infants who fail to engage in joint attention behaviours are almost certainly on an autistic developmental trajectory. Joint attention, which involves children's co-ordinating attention between themselves, an object and another person involves what Bakeman and Adamson (1982) refer to as *triadic deployment of attention*. A similar conceptualisation of the child's relation between self, other and objects of shared attention is put forward by Hobson (1993), who argues that the core of autism is a difficulty with the patterning of affectively charged interactions with other people. Earlier on we saw how difficulties with emotion spill over into the memory performance of individuals with ASD. But Hobson's characterisation of the structure of interpersonal relatedness and its role in the development of symbolic understanding also invokes the child's developing awareness of themselves in relation to another person and to objects to which both themselves and that person also stand in relation (see Hobson, 1993, pp140-153). In a similar vein, albeit from a radically different theoretical perspective, Leslie's (1987) analysis of children's understanding of pretence and mental state representation emphasises the importance of the child's developing awareness of *action-centred representations*, metarepresentations or M-representations (Leslie & Roth, 1993, see footnote 1). This development marks an enlargement of the child's conception of objects from one which considers their true identity (e.g. a banana as a piece of fruit) to one where they can also be defined in terms of the pretend actions of an agent (e.g. Mummy pretends that the banana is a telephone). This last development involves the child's being able to coordinate its own relation to the object with that of another person's relation to it in the context of a playful interpersonal exchange. Both Leslie and Hobson see autism as resulting from a breakdown in their respective systems, and the position advocated here is that the two systems may be different manifestations of a wider difficulty with processing ternary relations, which also has repercussions in the domain of memory.

A final advantage of adopting Halford's relational complexity account is that it elaborates on a position first advocated by Minshew and her colleagues (Minshew et al., 2001) who argue that autism is a disorder of complex information processing. This position makes intuitive sense when the pattern of performance across memory tasks identified by Minshew and colleagues is considered, but runs the risk of circularity by defining any task that poses difficulty for people with ASD as being 'complex', without establishing any *a priori* criteria for what constitutes complexity. Relational complexity allows predictions to be made in advance about which tasks should be easy and which difficult for individuals with ASD. In addition, its resonance with other behavioural characteristics of ASD suggests that difficulties with ternary relations may be a pervasive cause of a range of psychological atypicalities in this population.

4.0 Memory and the Brain

An important development in the typical memory literature in recent years has been an increasing refinement of our understanding of how the brain mediates our capacity to remember the past. In combination with our growing knowledge of memory in ASD, this development can help to enhance our understanding of functional and structural brain atypicalities in that population. The literature on structural brain atypicalities in ASD is converging on four broad themes. First, studies of brain size indicate that the brains of individuals with ASD are often larger than normal and that the developmental trajectory of brain size is atypical (Akshoomoff, Pierce & Courchesne, 2002; Aylward, Minshew, Field, Sparks & Singh, 2002; Courchesne, Karns, Davis et al, 2001). Second, neurological abnormalities at the cellular level have been reported for the cerebellum, the frontal cortex and certain Medial Temporal Lobe (MTL) structures such as the hippocampus and the amygdala (see Bachevalier, 2000; Bauman & Kemper, 2005; Casanova, Buxhoeveden , Switala & Roy, 2002; DiCicco-Bloom, Lord, Zwaigenbaum et al., 2006; Palmen, van Engeland, Hof & Schmitz, 2004 for relevant reviews). Third, functional imaging studies indicate abnormalities in these same regions, particularly MTL structures and the frontal lobes (e.g. Bachevalier & Loveland, 2006). Finally, behavioural and neuroscientific evidence is starting to converge on the idea that MTL structures and the frontal lobes are characterised by abnormalities in their functional connectivity with one another and with other areas of the brain (e.g. Gaigg & Bowler, 2007; Bachevalier & Loveland, 2006; Just, Cherkassky, Keller et al., 2007; Rippon, Brock, Brown & Boucher, 2007). It is perhaps no coincidence that two of the three brain regions that manifest greatest structural abnormalities in ASD are also those that are implicated in memory, especially those aspects of memory that appear to operate atypically in this population. Although we should be careful about seeing 'memory' as residing in one or more specific areas of the brain (see Graham, Lee & Barense, 2008 for discussion), there is now a broad consensus that declarative memory is mediated by frontal and MTL structures (see Brown & Aggleton, 2001 for review).

Support for some frontal involvement in memory in ASD is evidenced by the greater need of these individuals for task support in memory. The need for task support is also a characteristic of memory in typically ageing individuals, especially those in whom there is a suspicion of frontal lobe dysfunction evidenced by diminished performance on executive function tasks (Craik & Anderson, 1999; Craik, Morris, Morris & Loewen, 1990). Similarly, patients with acquired frontal lobe damage also show a pattern of performance across memory tasks that is not dissimilar to that seen in people with ASD (Schacter, 1987). More specifically, such frontal lobe patients exhibit difficulties with minimally-cued recall and episodic memory tasks whilst their performance on tests of recognition memory is undiminished. Together with the literature on executive dysfunction in ASD (see Hill, 2004a,b for reviews), this parallel between ASD, typically aging and frontal lobe patients provides converging evidence for frontal dysfunction as a component of memory difficulty in ASD.

Although the arguments for frontal contributions to memory in ASD are strong, there is increasing evidence pointing to the involvement of other brain areas. In typically-developed individuals, the most severe memory disorders result from damage to the medial temporal lobes, especially the hippocampus and associated structures of the ento- and peri-rhinal cortices and the amygdala (see Mayes & Boucher, 2008 for review). It was this observation that led Boucher and colleagues (Boucher, 1981; Boucher & Warrington, 1976) to suggest that autism might be a variant of the amnesic syndrome and as such would involve medial temporal structures. In the period since this earlier work, which was carried out mostly in children with severe and low-functioning

ASD, this view has been less and less advocated (see, for example, Bowler et al., 1997). The reason for this change is partly because it is evident that individuals with ASD are not amnesic in the same way as individuals with severe temporal lobe damage are, but also because our conception of 'autism' has enlarged to a spectrum view that encompasses subtler forms of the condition and includes individuals of normal cognitive and language ability and who therefore present subtler forms of memory difficulty. Nevertheless, the most recent empirical findings are prompting a return to a consideration of medial temporal lobe structures as contributing to atypical memory in ASD.

The capacity to recollect context implies that the disparate elements that constitute an episode have to be bound together in memory in a way that enables subsequent retrieval. There is now considerable evidence that this relational binding is mediated by the hippocampus (Brown & Aggleton, 2001), whilst related medial temporal lobe structures such as the perirhinal and entorhinal cortices mediate the processing of individual elements. As noted in the previous section, the patterning of memory in ASD suggests that such individuals experience difficulties in processing relations amongst elements of experiences in memory whilst their processing of the individual elements seems preserved. Recall, for instance, the observation of diminished recognition of episodically-defined combinations of elements in the presence of undiminished recognition of the individual elements themselves (Bowler et al., under review, a), or of diminished influence of item-context relatedness on recall but not on recognition of context (Bowler et al., 2008b), or the finding that individuals with ASD experience relatively specific difficulties in drawing on relations amongst words to facilitate recall whilst their use of information specific to individual words is undiminished (Gaigg et al., 2008c). All of these findings, together with the general difficulties in episodic memory characterising ASD, strongly suggest compromised hippocampal and spared perirhinal and entorhinal functioning in this population. In addition, this framework is compatible with the analysis of complexity by Halford (1992) and thus provides a useful starting point for investigating the importance of relational information in other cognitive domains such as 'Theory of Mind' and logical reasoning. Many theorists argue that an important function of the hippocampus is the ability to encode objects, events and relations among them rapidly and in a way that allows the adaptive use of encoded information in different settings (Eichenbaum, 2000). This ability is evidenced by tasks such as *Transitive Inference* (TI) in which an individual can infer that A>C having been told that A>B and B>C. TI performance is reflected in hippocampal activation (Greene, Gross, Elsinger et al., 2006), is sensitive to hippocampal damage and seen in people with amnesia (Smith & Squire, 2005). On the basis of the arguments presented here on diminished relational processing in ASD, we would predict diminished TI performance in this population and, moreover, would predict that TI performance would correlate both with those aspects of semantic organisation of material – clustering and the use of categories to aid recall - that pose difficulty for people with ASD, and with measures of binding and memory as well as measures of episodic remembering.

In an earlier section, we noted that an important characteristic of episodic memory is an awareness of self in time. Although the evidence from the domain of memory does not suggest that abnormalities in the experience of such temporally extended self-awareness is solely responsible for the episodic memory difficulties evident in ASD, abnormalities in this domain may nevertheless contribute to it. Given the close relation between self-awareness and episodic remembering, it is therefore possible, and perhaps even likely, that neural correlates of self-awareness are compromised in ASD. There is currently considerable debate about the neural correlates of self-awareness (see Feinberg & Keenan, 2005; Keenan, Rubio, Racioppi et al., 2005; LeDoux, 2003; Morin, 2005) and although some recent studies suggest abnormalities in this domain in ASD (Chui, Kayali, Kishida et al.,

2008) more work is clearly needed before one can draw any conclusions.

Although the patterning of memory functioning in ASD is consistent with the idea that it stems from hippocampal dysfunction, albeit with some frontal involvement, it does not follow that such atypical function results from hippocampal damage *per se*. The hippocampus receives rich sensory information from a range of cortical and sub-cortical areas of the brain via the enthorhinal cortex, which in turn relays information from the hippocampus back to a host of cortical areas (e.g. Squire, 1992). This arrangement is ideal for its function in relation to episodic memory and relational processing as it is in a position (literally) to integrate information processed in various different parts of the cortex and also modulate the processing of information in those cortical areas accordingly. It also means, however, that the patterning of memory functioning in ASD is not necessarily a reflection of hippocampal dysfunction but it could also be the result of atypical connectivity between the hippocampus and functionally associated areas. Or the information flowing along those pathways could be abnormal. Both the empirical and theoretical literature offer some support for these possibilities. As mentioned above, a considerable amount of evidence suggests that disparate brain areas are abnormally connected in ASD (e.g. Rippon et al., 2007) suggesting that the hippocampus may receive inadequate input, or may have difficulty in adequately transmitting outputs. The finding that emotional arousal atypically modulates forgetting in ASD (Gaigg & Bowler, 2008), is particularly relevant in this context, since such modulation is widely thought to be mediated by interactions between the amygdala and the hippocampus (e.g. Hamann, 2001). It is also possible that the information from primary sensory areas that is marked for bound representation by the hippocampus is atypical because of compromised functioning in those areas. This account has resonances with the *Enhanced Perceptual Functioning* model of ASD advocated by Mottron and colleagues (Mottron, Dawson, Soulières et al., 2006). Their argument is that the processing of information by people with ASD is characterised by the retention of lower-level perceptual features that remain available even when higher-level, conceptual processing has taken place. This has consequences in situations where typical individuals process in a predominantly global or conceptual manner. In such situations, individuals with ASD have the choice to process either perceptually or conceptually, often producing atypical performance patterns. There is some evidence that this happens in memory. Bowler et al. (2008a) found that adults with ASD showed less inter-individual convergence of subjective organisation of unrelated words than did typical individuals, suggesting that whereas the latter group organised words along semantic/associative lines, the ASD group may, in addition to this strategy, have organised the words along more perceptual features such as phonology or number of syllables. What is needed to confirm this account is a series of demonstrations of enhanced perceptual influence on psychological processes other than memory.

The argument just outlined leaves open the possibility that atypical hippocampal function may be the result of structural or functional problems elsewhere in the brain, which modify information fed to the hippocampus. But it ignores one fundamental aspect of ASD, namely that they are a set of *developmental* disorders, that is to say that they affect the trajectory of development of the individual in a way that yields an atypical endpoint. We can reasonably expect this atypical developmental trajectory to be as evident in brain structures as in adaptive behaviour. So, for example, it may be the case that enhanced perceptual functioning may feed information to the hippocampus in a manner that influences the bindings it makes, and that these different bindings in turn affect the way in which the hippocampus develops and influences processing in other brain areas. There is some evidence from the neuroimaging literature that is consistent with this position. Schumann, Hamstra, Goodlin-Jones et al. (2004) report atypical development of the hippocampus in children and adolescents across the autism spectrum. They also report atypicalities in the development of the amygdala in these groups. As we have seen, the amygdala plays an important role in emotional memory. In view of the connectivity between the hippocampus and the amygdala (Smith, Stephan, Rugg et al., 2006), it can be argued that diminished emotional modulation of memory in ASD is a specific aspect of more general difficulties with binding in memory.

5.0 Conclusions

It is now well established that ASD is characterised by a particular pattern of spared and impaired performance across different memory tasks. This pattern points to difficulties in the processing of information in ways that require binding of those elements of experience that uniquely define episodes, in the flexible relations among features that can be organised hierarchically, and in the emotional modulation of memory. Processing of individual items by contrast is relatively spared. All these types of processing implicate different structures of the medial temporal lobe of the brain, most particularly the hippocampus, the amygdala and the entorhinal and perirhinal cortices, as well as modulation of the functioning of these areas by the frontal lobes. Although these implications have yet to be systematically tested, they are consistent with the current state of knowledge of the development of these structures in the autistic brain. What also needs to be established is the extent to which atypical developmental trajectories in these structures are the result of abnormal input that results from atypical processing in other brain areas or to some initial damage to the structures themselves. As well as providing a framework within which to test neural underpinnings of psychological underpinnings in ASD, the behavioural findings in memory also provide a window into the inner experience of these individuals by showing that they have diminished self-involvement in their memories for past experience and that the quality of these experiences, the connections that the individual makes between experiences and the here-and-now consequences of a particular memory can at times be radically different from those of a typical individual.

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