Who's Talking? The Effect of Personalised Voice on Speech Generating Devices for the Child with Autism

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By

Susan Ní Chuileann

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This book is dedicated to my parents, Aidan and Evelyn Cullen.

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PREFACE

This book is a focus on the importance of voice for a child with autistic disorder. It is in part an exercise in education, and, in part, a story of my life. In relation to the latter, my youngest son, Evan, was diagnosed with autistic disorder in 1999 when he was almost three years of age. He has never functionally used speech over the past twenty years of his life, but he has used a number of devices and strategies to communicate his needs to others during those two decades. One of the most popular communication tools available for him was the speech generating device (SGD), which is an electronic aid used to produce digitised or synthesised speech upon activation by an individual with little or no speech.

The SGD was special because, for the first time, Evan had a voice! I recall him sitting on a swing-bench in the garden and typing his thoughts into the SGD before squealing with delight when they emerged vocally from the device seconds later. At last, he could express his needs vocally to anyone in earshot. He was so very empowered by this small, inexpensive gadget, which produced vocal sounds.

However, the voice on the device did not resemble his own in any way at all. It sounded electronic, with a slight American accent that was devoid of much inflection or emotion. It also struggled to pronounce certain words, which caused some hilarity for Evan’s brothers and sisters, but at times, great frustration for Evan himself. It struck me that perhaps Evan was not using the device to communicate as often as he could because he could not truly identify with the voice of that particular system. In addition, there was a distinct possibility that as family members, we did not engage as much as we should have done with Evan because of a subconscious lack of acceptance for the electronic voice on his SGD.

Fortuitously, research was coalescing to develop technology that performs a voice transplant of the child's natural voice onto the augmentative and alternative communication (AAC) device, so that the device's voice would sound like the child’s own (www.nlmfoundation.org). This is where my book becomes somewhat educational.

Researchers were beginning to hypothesise that an AAC device with a personalised voice that mimics the child's voice, could only serve to psychologically reinforce powerful motivational factors and a sense of ‘owness’ for communication so that the frequency and richness of AAC use, and its acceptance by family members and friends, would be enhanced. In addition - as a tool for improving a child’s speech capabilities - a system that could speak with a voice similar to the child's own voice would likely be more effective than a system that could speak with a default synthetic voice. The computer could provide a model that is closer to the child's speech and hence would be easier to emulate by the child.

To understand all this a little better, I did some research of my own and soon I was enthralled by the study of voice. It was fascinating to discover that voice is much older than speech for instance. It became apparent that speech appeared only relatively recently in evolution as a particularly complex and abstract use of voice by the human species (see Fitch, 2000; Hauser, 1996). Indeed, it was vocalisations that were most prominent in the auditory environments of vertebrates for, ‘millions of years before speech emerged’ (Fitch, 2000: 258). Furthermore, the ability to accurately decode the information contained in these vocalisations (e.g., are you a friend or foe, male or female, child or adult) had great importance for survival (Fitch, 2000).

I quickly learned that voice is the result of a source in the larynx filtered by the supra-laryngeal vocal tract (Belin et al., 2004; Fitch, 2000). The chest, throat, tongue, lips, and weight all affect the sound quality of a person’s voice (Cavarero, 2005). Minute inter-and-intra-individual variations around those structures mean that each voice is as different as each being that sends their vocalisations into the air. It is directly influenced by our age, gender, culture and vocal habits (Spence, Rollins, & Jerger, 2002). This explained why no two people ever sound the same, and no two utterances by the same person are ever identical (Ambridge & Lieven, 2011), and led me to understand that voice manifests the unique *being* of each human being. As a result, I began to realise how important a natural voice on a SGD would be for me, my family, and in particular, my son.

However, would he want this? Would he like the sound of his own voice on this communication device? Moreover (possibly more to the point), given his diagnosis, would he *recognise* the sound of that voice on the device as being that of his own? How easy is it for a typically-developing (TD) child to recognise self-voice? How important is it, for the child with autistic disorder, to listen to any voice? These questions formed the basis of much study for the next four years. I immersed myself into the recruitment of participants, the procurement of SGDs as test material, and the analysis of numerous studies. This book is the outcome of those four years.

In writing this book, the main aim is to provide the reader with an exciting yet accessible introduction to the role of voice as a marker of identity. The book provides a broad overview of this phenomenon, and, at the end of the book, a list of further reading for each chapter is provided.

This is my first venture in writing a book. The research and writing often took place well into the small hours after a long day lecturing psychology in a small College in Ireland, and then involving myself in being a mother to four young adults. After each draft chapter was completed, I had often forgotten birthdays, school collections, and the paying of important bills. Therefore, it is with special gratitude that I extend thanks to all of my family, and to my partner, Anthony. I also need to express sincere gratitude to: The staff and students of Carlow College, Co Carlow, Ireland, for their patience and for listening to the woes of book-writing over the past year or so; to Sam Baker and the team at Cambridge Scholars Publishing for their encouragement, support and advice; and last but never least, thank you to my son, Evan, whose diagnosis of autism taught me more about myself than I care to mention.

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Finally, I wish to extend special thanks and gratitude to my four beautiful children; Shane, my eldest son and my rock, Rebecca, my beautiful and witty daughter, Rachel, a little jewel and a gorgeous daughter, and of course, Evan, my youngest son and my very precious snowflake. Thank you one and all.

INTRODUCTION

Autism Spectrum Disorder (ASD) is characterised by impairments of social interaction and communication, accompanied by rigid interests and repetitive behaviours (Eigsti, et al., 2011; Lord & Paul, 1997; Rogers & DiLalla, 1990). Some of the specific communication difficulties associated with autism include the following: Delayed language acquisition (Dahlgren & Gillberg, 1989; De Giacomo & Fombonne, 1998; Eigsti et al., 2011); deficits in pragmatics and discourse processes (i.e., how language is used) for those with a diagnosis of Asperger Syndrome (Rutter, Mawhood, & Howlin, 1992); and echolalia, or the immediate or delayed imitation or echoing of language the child has heard from other speakers or from media, such as TV shows or cartoons (Tager-Flusberg & Calkins, 1990).

While language and communication impairments are present across essentially all individuals with autism (Eigsti, et al., 2011; Lord & Paul, 1997; Rogers & DiLalla, 1990), the child with autistic disorder is distinguished by an even more severe, towards profound, set of language and learning difficulties (Boucher, Mayes, & Bigham, 2012; Eigsti et al., 2011). For instance, there are suggestions that up to 25% of these children never acquire functional speech across their lifespan (Eigsti, et al., 2011; Lord & Paul, 1997; Rogers & DiLalla, 1990).

One method of enhancing the communicative abilities of individuals with autistic disorder has been the development of augmentative and alternative communication (AAC) devices (Boesch, Wendt, Subramanian, & Hsu, 2013; Koul, 2003). Defined as the supplementation, or replacement, of natural speech through alternative means of communication (Sigafoos & Drasgow, 2001), two of the most common forms of AAC for the child with autistic disorder currently comprise sign language and the Picture Exchange Communication System (PECS) (Bondy & Frost, 1994).

One of the most basic and popular forms of AAC for the non-verbal, or minimally verbal, child with autism is the use of manual signs (http://www.lamh.ie). Manual signs have been successfully used as a mode of communication for children with autism who do not speak (Paul, 2008; Tager-Flusberg, 1999). Children with autism have been known to adapt reasonably well to this form of communication (Goldstein, 2002), but Seal & Bonvillian (1997) have suggested that, as the acquisition of signs is related to fine motor skills, some children with autism - with low levels of fine motor abilities - are less likely to benefit from this form of AAC.

Another very popular form of AAC for the child with autism is that of picture exchange communication systems (PECS; Bondy & Frost, 1994). PECS involves the, 'systematic instruction of self-initiated communication skills using six phases' (Boesch et al., 2013: 481). It begins with teaching a single word request, by means of exchanging a picture for an object, with learned behaviour systematically built on in order to achieve more communicative independence (Boesch et al., 2013). In the final phases, it is anticipated that PECS users will be able to make more detailed requests (e.g., '*I want to go for a drive with Dad'*) and make comments (e.g., '*It is a very sunny day today*'). While PECS is readily adapted for children with autism (Goldstein, 2002; Paul, 2008), probably based on the observation that children with autism prefer visual stimuli over auditory stimuli (Mirenda & Schuler, 1988; Schuler & Baldwin, 1981), very few achieve level six communicative ability (Boesch et al., 2013).

One of the most significant advances in AAC has been the development of voice operated communication aids (VOCAs) or speech generating devices (SGDs) (see Boesch et al., 2013; Koul, 2003; Sigafoos & Drasgow, 2001; van der Meer & Rispoli, 2010). The SGD can be defined as, 'an electronic communication aide that produces digitised or synthesised speech upon activation by individuals with little or no functional speech' (Boesch et al., 2013: 481). Unlike sign or PECS, the SGD is designed to emit a 'voice,' providing the child with the ability to express verbally their needs (Shane, Laubscher, Schlosser, Flynn, Sorce, & Abramson, 2011). These devices allow the child to communicate verbally with anyone within earshot (see Sigafoos & Drasgow, 2001; van der Meer & Rispoli, 2010).

The typical SGD varies widely in terms of cost, appearance, functions, and features (Boesch et al., 2013). Many use a text-to-speech synthesis design, in which, 'alphabets, digits, words, and graphic symbols are entered from an input such as a keyboard/switch/touch screen, and are converted into a speech waveform using a set of algorithmic rules' (Koul, 2003: 49). Others are very low-tech in their design and comprise no more than 24 pictures, which emit speech sounds when touched by the child (http://www.assistireland.ie).

Specifically, the SGD addresses a general problem with AAC tools (such as manual sign and PECS) insofar as the speech output function on the SGD facilitates a more independent mode of communication for the child with autism (Mirenda, 2001). For instance, much like natural conversation, the voice from one of these systems is immediately available to anyone within hearing distance and, unlike sign language or PECS, there is *no expertise* required on behalf of the listener to understand the child's message (Boesch et al., 2013). In addition, children with autism adapt well to SGDs as it is well established that these children are naturally drawn to technology and digital media (Dautenhahn, 1999; Kee, 2012). This positive adaptation of the SGD by the child with ASD is likely because these electronic devices provide a safe, reliable, and predictable outcome - an effect typically preferred by children with autism (Billard, Robins, Nadel, & Dautenhahn, 2006).

Moreover, these devices fit in with a contemporary *zeitgeist* where technology is pervasive and tightly meshed into a host of speech generating platforms commonly used for work, life, and leisure (Kee, 2012). Overall, for the linguistically challenged child with autism, of all AAC currently available, the ability of the SGD to project a voice provides the child with low-functioning autism (LFA) a potential means of overcoming several barriers to inclusion, participation, and social interaction (Beukelman & Mirenda, 2012). This AAC, and this AAC alone, gives the child with autism a voice.

However, the voice is either digitised, or synthesised, in its composition (Lloyd, Fuller, & Arvidson, 1997). As an example, consider the speech output produced by the SGD of the British physicist, Stephen Hawking (http://www.hawking.org). While digitised voice utilises recorded human speech, synthesised speech devices use computer-generated speech. The voice output on Professor Hawking's device is synthesised in its nature. There are pros and cons to both types of voices. Digitised SGDs, although more 'normal' sounding, are limiting because they can only say the words or phrases programmed on the device. They do not allow for free-thinking. Synthesised SGDs allow the user to have pre-programmed phrases or words, but also have the ability to spell out novel thoughts (Lloyd, Fuller, & Arvidson, 1997). In either instance, the voice of a SGD does not resemble in any way the voice of the child with autism using the device (see van Santen & Black, 2009).

It is exciting, and of interest therefore, that researchers began to consider finding a way for the voice of a minimally verbal child to be transplanted onto SGDs (Klabbers, Kain, & van Santen, 2010; van Santen & Black, 2009). This simple and yet stunningly creative innovation would appear to make maximum sense given the role of voice as a marker of self, and a signal for identification to others (see Belin et al., 2004). However, while those listening might better recognise this voice rich in accent, dialect, age, gender and ethnicity, it seemed important to me to ascertain whether, or not, the child using the device could also.

In relation to listening, there is evidence that adults, 'encode and maintain information about characteristics of voices and that this speaker-specific knowledge facilitates their processing of linguistic information' (Spence, Rollins, & Jerger, 2002: 215). For instance, a study assessing adult listener's abilities to identify words and sentences by Nygaard and Pisoni (1998) found that performance was more accurate when the voices heard were of people that were familiar to them as opposed to voices of unfamiliar people. There is also evidence to suggest that adult listener's judge a heard word as 'old' more accurately if the same speaker, at familiarisation and test, speaks the word, as opposed to when different speakers are used (Palmeri, Goldinger, & Pisoni, 1993).

This raises questions about what types of attributes are encoded and essential for recognising a speaker and whether these attributes are linked/related to semantic knowledge (e.g., name, age, gender, and role) about the identity of the speaker. Studies conducted with adults, using no more than eleven speakers uttering sentence-length voice samples, demonstrated speaker-recognition rates above 97% (Abberton & Fourcin, 1978; Bricker & Pruzansky, 1976; Hollien, Majewski, & Doherty, 1982). It is now accepted that an adult's voice-recognition accuracy is directly influenced by the stimulus set size, the duration of the voice sample, and the listener's familiarity with the speaker's voice (Spence et al., 2002).

Research on the ways voice is recognised by the typically-developing (TD) child has begun to accumulate only in the last few decades. In a seminal study by Bartholomeus (1973), children's voice recognition, via both the auditory and visual modalities, was assessed on tests of tape-recorded speech samples obtained from their classmates, and teachers, five months after the start of the school year. In this study, the, 'absolute identification of normally recorded voices by naming was compared with identification of the same stimuli by matching voices to pictures of faces' (Bartholomeus, 1973: 465). The results of this study suggests that by the age of four years, the ability of the child to recognise the voices of familiar people is at a near-adult level, but it is not as accurate as their ability to recognise familiar faces (Bartholomeus, 1973).

A similar study (Mann, Diamond, & Carey, 1979) found age-related improvements between the ages of 6 and 10 years for children's recognition of recently encountered voices (Mann et al., 1979). Similarly, Strömbergsson (2009) tested 4-8 year old children's recognition of voices, and these children performed at near-adult level accuracy - but again showed wide variation in their scores (Shuster, 1998; Strömbergsson, 2009). Combined, the findings of these studies suggest that faces are easier to recognise than voices, and that the ability of children to recognise unfamiliar but recently encountered voices and faces develops more slowly than recognition of familiar voices and faces, which may not reach adult-level-performance until about the age of 14 (Mann et al., 1979).

What might this mean for the child with autism therefore? Certainly, studies of voice recognition in children diagnosed with autism spectrum disorder are less common. One study however - which assessed recognition via both auditory and visual modalities – tasked the relatively able schoolchildren with autism to match vocal recordings of staff members from their schools to photographs of the same people at test (Boucher, Lewis, & Collis, 1998). The findings of this study showed that the children with autism were impaired on this task compared to language-matched typically-developing children. Significantly, the researchers noted that the children with autism had had, 'rather more opportunities than controls for exposure to the adults whose voices and faces were used as stimuli given that they had been in school for longer than the controls' (Boucher et al., 1998: 180). This led the researchers to conclude that 7 to 9 year old children with autism, 'either did not, or could not, utilise these opportunities to achieve normal familiarity' (Boucher et al., 1998: 180).

A second recognition study, tapping both auditory (voice recordings) and visual modalities (photographs), was conducted with slightly older children with autism (Boucher, Lewis, & Collis, 2000). This time, no impairment was found in this group relative to language-matched children with specific-language impairment (Boucher et al., 2000). As such, the findings from studies of voice recognition in the child with autism are scarce, and provide mixed results.

Accordingly, I reached the conclusion that, while all over the world children learn to recognise the sound of their mother's voice - and then, slowly, but surely, the voices of people in their ever-widening social circles - the child with autism may find this function of development and experience somewhat more tasking. Why is this? Is it a lack of social motivation? Is it possibly a lack of interest in faces and voices? Alternatively, could it be a deficit of memory?

Memory is vital to development and to the acquisition of language in particular. The elaborate trajectory that children take in learning the diverse aspects of language is one of the most fascinating areas of human psychology—and one that is underpinned by memory—and is a journey you are now invited to follow with me.

CHAPTER ONE

MEMORY AND AUTISM

Arguably, all communication is supported by memory function. For instance, a typical conversation requires that the individual attends to, stores, and retrieves linguistic and contextual information almost instantaneously, while also producing, comprehending, and monitoring the production of words and sentences (Atkinson, 2002). We also rely on aspects of memory for communications that occur via digital media - such as Skype or video-links - with the most common device used to communicate across time and space being that of the mobile phone. Different facets of memory may be called upon when communicating via such mediums as the listener is tasked with recognising *what* is being said (e.g., perceiving the language, the words, and the content of the message), while also recognising *who* is speaking (analysing the age, the gender, the accent and identity of the speaker) (Kuhl, 2011).

Our focus is on the linguistically challenged child who communicates via voice-enabled augmentative and alternative communication (AAC) devices, or speech generating devices (SGDs). The aspect of memory we propose as the most relevant is that of recognition memory. Technology has developed so much that even small segments of the child's actual voice can be transformed via speech mimicry technology to create a SGD that sounds just like the voice of the child using it (Klabbers, Kain, & van Santen, 2010; van Santen & Black, 2009). Our focus is not primarily on the child's ability to recognise *what* is being said, but is on their ability to recognise *who* is speaking on the personalised SGD. If they can recognise the voice as that of their own, and come to prefer the voice-type - over and above any alternative available on the device - there is every possibility that the frequency and richness of AAC use, and its acceptance by family members and peers, will be enhanced (van Santen & Black, 2009). If not - if self-voice is neither familiar nor recognisable to the child - there is every chance that the device will be subject to complete or partial abandonment by the child (Van-Biervliet & Parette, 1999).

Memory in high-functioning autism (HFA) has been extensively researched in the past forty years (for reviews see Boucher & Bowler, 2008, 2010) and - while the behavioural findings generated have been variously interpreted - most commonly, a memory systems classification has been used as the basis of interpretation (Tulving, 1985). This means that when recognition performance fails or succeeds in autism, it is conceptualised as the consequence of impaired, or spared, systems of the memory. Significantly, this approach assumes memory can best be understood as a series of several functionally distinct systems (Nyberg, Cabeza, & Tulving, 1996; Tulving, 1982, 1985; Tulving & Markowitsch, 1998; Tulving & Schacter, 1990; Wheeler, Stuss, & Tulving, 1997). Within this, each system can be defined by a given criteria, such as the *type* of information it holds, and *for how long*, and the *levels of awareness* the systems give rise to in the individual (Gardiner, 2008).

Recently however, it has been suggested that we begin to discuss the findings on memory in autism, in terms of a dual-process model that cuts across pure systems-based distinctions (see Joseph, Steele, Meyer, & Tager-Flusberg, 2005). According to this approach, recognition is either accomplished, or not, on the basis of two distinct but mutually interactive processes - namely 'recollection' and 'familiarity' (Aggleton & Brown, 2006; Jacoby, 1991, 1998; Mayes, Montaldi, & Migo, 2007; Yonelinas, 2002).

This chapter is a journey with a set goal. We want to examine in minute detail the assumptions of these competing approaches to understanding memory, and the methods that have developed to evaluate these assumptions over the years. The aim is to illustrate how models of memory have evolved over the past fifty years, and while theory of autism was divided between theories of memory systems - or theories of memory processes - for much of this time, over the past few years some rapprochement between the two has begun (Gardiner, 2008). Our focus remains firmly on the child with LFA. Our central objective is to establish a theoretical framework and an appropriate method for investigating recognition performance in this child. Our journey begins with an overview of what we mean when we refer to memory, memory systems, and memory processes.

Memory has been described by some as 'a funny thing' (Hobson & Hermelin, 2008: xix). This is unsurprising when you consider that it is something that is used in the present, while required to conjure up the past, while also used to plan for the future. Memory affects how and what we perceive, and how what is perceived is understood, which in turn affects the ways in which we experience and react to our external world (Boucher, et al., 2012; Gardiner, 2008; Hobson & Hermelin, 2008). Undoubtedly, memory is a crucial aspect of who and what we are and the ways in which we understand and behave during our day-to-day lives. However, what is memory *exactly*? Is it something you can touch or examine like the 'brain' or the 'heart'? Alternatively, is it a construct like the 'soul' or the 'mind'? It obviously stores information and this information can be personal or factual; of what words and sounds signify; what we feel we know is linked with other things; what we once felt; and what we once saw (Hobson & Hermelin, 2008). So, is this information held in a box in our head? Is it one box or a number of boxes? How does information 'get into' the box or boxes, and how do we retrieve the information when we need it?

Obviously, memory is far more complex than the simple analogy of a box in the head, and it is often described in terms of systems and processes (Boucher & Bowler, 2008, 2010; Gardiner, 2008). There are suggestions that encoding and retrieval *processes,* and memory *systems,* are, 'the most fundamental hypothetical constructs in theory of memory' (Gardiner, 2008:4).

A memory system is commonly defined by a given set of criteria, such as the kinds of information it can hold, its rules of operation, its evolved function and, 'the conscious states' it may give rise to in an individual (Gardiner, 2008: 05; Sherry & Schacter, 1987). *Memory processes*, on the other hand, differ from memory systems insofar as processes refer to the ways that information is perceived, assimilated, stored, and retrieved by the individual. Process-related distinctions have previously been drawn between, 'deep and shallow encoding, item-specific and relational encoding; immediate (short-term) and long-term memory (LTM); rapid, single trial learning and slow, repetition-based learning; recollection and familiarity; effortful and automatic retrieval' (Boucher et al., 2012: 459). Currently, while it is acknowledged that contrasts between these two approaches have generated debate over the years, more recently there has been some rapprochement between them, with increasing appreciation that the two are actually quite complementary. For instance, different memory systems will necessarily involve encoding and retrieval processes (Boucher et al., 2012; Gardiner, 2008).

We note that much of what is known about autism arises out of a perspective that conceptualises memory as a set of several functionally distinct systems. Conceptualising memory in this way did not happen overnight however. The assumption that memory functions as a set of evolved and discrete systems, or structures, is theoretically motivated and built upon the findings of studies conducted over past decades.

One of the earliest scientific accounts of memory dates back to Hermann Ebbinghaus (1885). When he wrote the first scientific account of memory, he had no database of previous findings and had limited apparatus to guide his research. He conceptualised memory as, 'an indivisible complex entity' (see Tulving 1999:15). So, in a way, if we revert back to the 'box' analogy it appears that during this period of time, memory was considered much like a 'singular' box with one singular capability, function, and/or purpose (see Solso, Maclin, & Maclin, 2005; Tulving, 1999).

Over time, however, evidence for two memory stores began to emerge, primarily from physiological studies (Solso et al., 2005). For example, Weiskrantz (1966) found that performance by animals on learning trials decreased when the trials were followed immediately by electroconvulsive shock. That this arises while earlier learning remained intact suggested that a transfer from a short-term memory (STM) system to a more permanent memory system must be occurring.

Further support for two memory stores came from studies of patients suffering from amnesia, as these individuals presented with either no memory for the seconds prior to their head injury (short retrograde amnesia) or no memory for events experienced in the more distant past (long retrograde amnesia; see Solso et al., 2005). There was also compelling evidence for more than one aspect to memory, from studies of individuals with selective brain injury. For instance, Milner (1966) reported the case of a patient complaining of severe epilepsy who had surgery to relieve the symptoms, which involved taking part of the hippocampus. After the surgery, although the epilepsy was improved, it became obvious that the patient was profoundly amnesic, with practically no ability to form new long-term memories combined with intact short-term memory (Atkinson & Shiffrin, 1968; Milner, 1966). Combined, these findings dramatically changed the view of memory from that of a singular entity to that of a multi-store model (Atkinson & Shiffrin, 1968). What was also becoming apparent was the role of the hippocampus in the operation of memory (Milner, 1966). It is no surprise therefore to note that around this time, it was speculated that autism might derive in part from developmental amnesia, associated with hippocampal abnormalities (see Boucher et al., 2012; Rimland, 1964).

The Multi-Store Model of Memory

A theoretical framework for memory was proposed by Atkinson and Shiffrin (1968), which comprised a sensory register that received input from the environment, a short-term store (or working memory, which temporarily held information used to perform cognitive tasks), and a long-term store (Fig. 1-1).

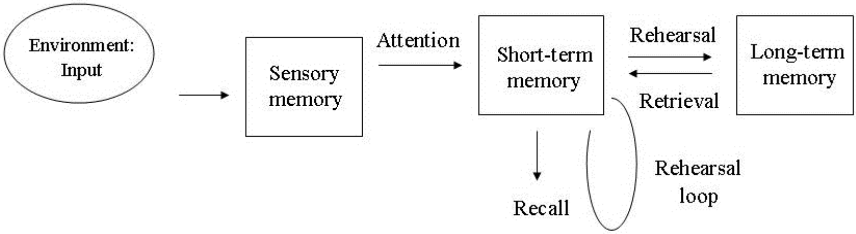

Fig. 1-1 The Multi-Store Model of Memory

Within this, the short-term store (STS) had a limited capacity while the long-term store (LTS) was limitless. The ability to forget from the STS was complete in 30 seconds or less, while forgetting from the LTS was either very slow or information was not forgotten at all (Atkinson & Shiffrin, 1968; Craik & Lockhart, 1972).

A limited set of processes were thought to comprise the encoding of information, certain rehearsal operations, and certain retrieval strategies (Gardiner, 2008). In a way, this multi-store model described memory as a type of system through which information flowed. For instance, via this model information is assumed to be detected by the sensory organs, whereby it then enters sensory memory. If this information is attended to, it enters the short-term memory, and in turn, if this information is rehearsed, it enters the long-term memory. It is further assumed that un-attended to or non-rehearsed material is subject to decay or displacement, otherwise known as forgetting (Atkinson & Shiffrin, 1968).

This model of memory drew criticism particularly in terms of it being a passive and linear model of memory (e.g., Murdock, 1972; Tulving & Patterson, 1968). It was also becoming apparent that the STS could not be considered as a more-or-less unitary system. For example, when tested immediately after material was presented, (and thus tapping the 30 second capacity of the STS), some individuals display no difficulty with the immediate recall of information that was presented visually combined with a poor immediate recall of information that was presented auditorily (Vallar & Baddeley, 1984). The reverse of this finding has also been noted whereby an individual displays difficulty with tasks requiring the manipulation of visual tasks, but no difficulty with the immediate recall of letters heard (Shallice & Warrington, 1974). These particular findings strongly suggest that short-term memory could not be construed as a singular, unitary system.

The Original Working Memory Model of Memory

To replace the more unitary view of short-term memory characterising the distinction between short-and-long term memory, Baddeley and Hitch (1974) developed what is now known as the 'original working memory model of memory' (see Fig.1-2). This model of memory consisted of three components: the central executive, the phonological loop, and the visuo-spatial sketchpad (Baddeley & Hitch, 1974; Baddeley, 2000, 2002).

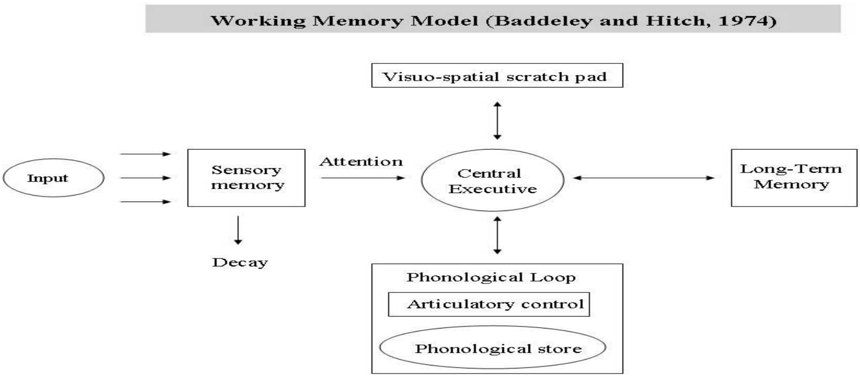

Fig. 1-2 Working Memory as Proposed by Baddeley and Hitch (1974)

The central executive, closely based on the attention control system of Norman and Shallice (1986), is thought to coordinate the operation of the phonological loop and the visuo-spatial sketchpad. The phonological loop has two components: a store, which temporarily holds verbal and acoustic information, and an articulatory rehearsal system capable of converting visually presented information into phonological code (Baddeley, 2006). The visuo-spatial sketchpad parallels the operation of the phonological loop (Baddeley, 2006), but for visual and spatial information (see also Gardiner, 2008).

Later, Baddeley (2000) introduced an additional component to the working memory (WM) system, known as the episodic buffer. The episodic buffer is conceptualised as a limited capacity storage system capable of integrating representations from the phonological loop, the visuo-spatial sketchpad, long-term memory and the perceptual system. Baddeley considered the buffer to be 'episodic' in the sense that it has the ability to integrate information across space and time. In line with Gardiner (2008: 7), the key purpose of the introduction of the episodic buffer is important as it acknowledges an increased understanding that the combination of information in WM, from different sources itself, requires some temporary 'holding mechanism' to bind this information together (see also Baddeley, 2000; Boucher, Bigham, & Mayes, 2012).

The WM model cannot be considered a general model of memory, however, as it only deals with one component of memory. Nevertheless, this model is clear evidence of the way our understanding of memory has evolved significantly over time.

Tulving's Taxonomy of Memory Systems

Over time, Tulving (1985) proposed an even more broad-based and encompassing model of memory. Based primarily on behavioural findings, this model identified *five* memory systems, one of which was working memory, and four of which corresponded to different representations of long-term memory - namely semantic, episodic, procedural, and perceptual representation (Gardiner, 2008: 6) (Fig. 1-3).

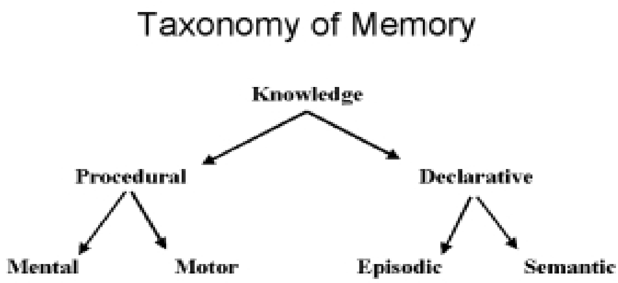

Fig. 1-3 Tulving's (1985) Taxonomy of Memory Systems

In this model, procedural memory refers to the acquisition and use of perceptual, cognitive, and motor skills *and* involves the sensation of 'knowing' how to do something (Tulving, 1985). This type of memory represents accomplished skills and/or behaviours, such as walking, running, cycling, and dressing oneself (Schacter & Tulving, 1994), which is typically acquired through extensive practice (Boucher et al., 2012). Procedural memory, therefore, includes memory for motor, perceptual, and cognitive skills, and various kinds of conditioning, and priming (Mayes & Boucher, 2008). Perceptual representation memory involves the storage of the form or structure of visual objects and words (Schacter &

Tulving, 1994). This too is thought to operate primarily at a level of non-consciousness. Both perceptual and procedural memory form part of the nondeclarative memory system.

Declarative memory is divided into semantic and episodic memory. Consider your own memory for a moment. Can you remember a childhood Christmas, a first day at school, a first kiss, the smell of lemon trees as you holidayed in Sicily? According to Tulving, our memory for personally experienced events is underpinned by episodic memory, which represents one of two components of the declarative memory system. The second component of this long-term memory system is semantic memory, which represents our memory for general knowledge and decontextualized facts (Boucher et al., 2012; Schacter & Tulving, 1994; Tulving, 1985).

The key difference between episodic and semantic memory is thought to be the level of conscious awareness at which retrieval takes place (Gardiner, 2008; Tulving, 1985, 2000; Wheeler, Struss, & Tulving, 1997). Specifically, episodic memory is said to operate at the autonoetic level, and is thought to be characterised by a sense of 'remembering' (Tulving, 1985) or awareness of reliving a previously experienced event (Tulving 1983, 1985). Just to be certain, try recalling those memories of a childhood Christmas, or your school days again. You can probably smell the pine, or remember your teacher's face and maybe even her name. Specifically, it does appear to require effortful and controlled mindfulness at the point of recall. Semantic memory, (e.g., knowing what day Christmas Day falls on), operates at a more automatic, or noetic, level and is better characterised by a sense of 'knowing' (Tulving, 1983, 1985). In particular, this type of memory only requires recalling the date without having to bring to mind any memory of how, or when, you acquired that knowledge.

It is suggested that semantic memory is evolutionarily older than that of episodic memory (Tulving, 1985, 2002) and, while semantic memory can operate independently of episodic memory, many operations of episodic memory remain dependent on semantic memory (Gardiner, 2008). For example, while information can be 'placed' into semantic memory but not into episodic memory, the reverse cannot happen. This implies a very clear role for semantic memory therefore, insofar as it includes information about personal history, but this is known in a detached, factual way, without any accompanying feeling of mental time travel (Gardiner, 2008; Lind, 2010).

Overall, it would appear that memory is clearly explained via a systems taxonomy, as the findings of a number of behavioural and physiological studies do lend support to the suggestion of particular systems processing different types of information (i.e., perceptual,