Tactile Sensitivity in Typical and Atypical Development

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Abstract

The tactile sense is fundamental for typical development yet has been largely under studied in comparison to other sensory modalities of vision and audition. Some individuals exhibit unusual behavioural responses to sensory stimulation that would normally not be considered to be noxious. There has been an increase in research exploring these unusual sensory abnormalities over the last 10 years. Previously only reported anecdotally, some individuals are aversive to or withdraw from tactile stimulation. Referred to as *tactile defensiveness*, this unusual tactile response has been explored primarily with the use of questionnaires. Literature reports both over-responsivity (hyper) and under-responsivity (hypo) to tactile stimulation in atypical development, for example exhibiting negative response to social touch or an extreme fascination with certain tactile stimulation. Tactile defensiveness affects many facets of behaviour, including motor development, learning and social interaction. In some extreme cases, individuals with tactile defensiveness will avoid human contact. To date, there is no systematic research examining tactile sensitivity in typical or atypical development despite these negative consequences for many aspects of development.

This thesis aims to explore tactile sensitivity in typically developing individuals and those individuals most likely to have sensory abnormalities, specifically Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). Chapter one summarises literature on the importance of touch for development and introduces theories of tactile defensiveness. A questionnaire study explores texture preferences and aversions in Chapter two. Since little is known about texture preference in either typically developing children or those with ASD / ADHD the purpose of the questionnaire was to create a baseline of texture preference. A further

study explored preference for texture complexity. Contrary to expectation, no differences in texture preference were found between comparison groups. Since no differences in texture preference were found, it was predicted that perhaps differences in unusual tactile response may be due to heightened sensitivity to texture for those individuals with sensory abnormalities. Chapter three investigated tactile sensitivity to fine texture and predicted that individuals with ASD would be more accurate at texture discrimination than typically developing individuals. No group difference was found in texture discrimination. In Chapter four, cross-modal matching of texture was explored. It was proposed that unusual tactile response observed in individuals with ASD may be due to difficulty matching visual and tactual information. In a series of studies, results found that individuals with ASD were impaired at matching texture information cross-modally. The inability to accurately match visual-tactual texture information may contribute to the negative tactile reactions observed in individuals with ASD and may provide insight into a possible contributing factor to tactile sensitivity in atypical development.

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Chapter One

General Introduction

1.1 Touch, Development and Tactile Defensiveness

Touch is a significant means of communication, and one of our most basic ways of interacting with the environment, thus plays a crucial role in development. However, some individuals react adversely to tactile stimuli that would ordinarily be considered non-offensive, or pleasurable. The term *tactile defensiveness* has been used to describe this unusual tactile response. Tactile defensiveness was derived from the Sensory Integration Theory, proposed by Ayres (1972). Ayres' Theory of Sensory Integration was developed within the field of Occupational Therapy, with its main purpose to identify and describe behaviours associated with difficulties processing sensory information. According to the theory sensory integration is defined as "*the neurological process that organises sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment*", (Ayres, 1972, p.11). The definition highlights the emphasis placed on active participation of the individual in its environment. The inability to process sensory information from the body and environment was referred to as Sensory Integration Dysfunction (SID; Ayres, 1972). The theory of sensory integration (SI) proposes that SI dysfunction manifests itself in two main ways, i.e. poor praxis (a difficulty with motor action and motor planning) and poor sensory modulation (modulation dysfunction; Ayres 1969). There are four separate ways in which deficits of sensory modulation dysfunction can manifest, specifically, *sensory defensiveness* (including tactile defensiveness), gravitational insecurity, aversive responses to movement, and under-responsiveness (e.g. Mulligan, 1998, 2000). Sensory defensiveness[1] refers to the avoidance or sensation seeking behaviour of individuals to certain stimuli that would not normally elicit such behaviour. The term tactile defensiveness therefore falls under the umbrella term Sensory Integration Dysfunction (modulation dysfunction), now currently referred to as Sensory Processing Disorder (Miller et al., 2009).

[1]In the literature concepts overlap and are not clearly defined i.e. sensory defensiveness usually refers specifically to the aversive or avoidance response of individuals to stimuli. (over-responsivity when particularly referring to tactile modality), and yet sometimes sensation seeking responses are associated with the same concept (where 'seeking' behaviour is associated with under-responsivity or a higher tolerance threshold for sensory information).

Sensory defensiveness has been observed in all the sensory systems, however was first described in the tactile system. According to Ayres (1963) tactile defensiveness "*is characterised by deficit in tactile perception, by hyperactive, distractible behaviour, and by a defensive response to certain types of tactile stimuli"*, (p.225). It has been revealed that tactile defensiveness may affect many aspects of behaviour, including the development of perceptual motor ability and learning (Ayres, 1971). Parent-child relationships and later peer interactions may also be affected by this integrative deficit (Larsen, 1982). More recently, tactile hyper-responsivity / over-responsivity[2] has been found to be the most common and pervasive symptom (Reynolds & Lane, 2008). Over-responsivity has been identified as the most common form of Sensory Modulation Dysfunction, with approximately 80% prevalence in individuals referred to research programs (Schaaf, 2001).

In a study describing sensory defensiveness in adults, Kinnealey, Oliver & Wilbarger (1995) emphasise how distressing sensory defensiveness can be to the individual, contributing to unusual behaviour patterns and coping strategies that are not deemed socially acceptable and are emotionally exhausting, such as the deliberate avoidance of unfamiliar situations and physical contact (e.g. hugging / shaking hands), organising and controlling situations, and confronting identified sources of sensory annoyance. These coping strategies interfere with the quantity and quality of interpersonal experiences and relationships. In the study, sensory defensive symptoms were most prevalent in the tactile domain, i.e. tactile defensiveness. In support of this, a recent twin study by Goldsmith, Van Hulle, Arneson, Schreiber & Gernsbacher (2005) exploring tactile and auditory defensiveness in autism found that tactile sensitivities are more heritable than auditory sensitivities. Tactile defensiveness is central to the construct of sensory defensiveness and has been described in more detail than any other type of sensory defensiveness (Baranek, Foster & Berkson, 1997). Tactile defensiveness, which is characterised by behaviours such as negative reactions to every day stimuli, rubbing, scratching, withdrawal or even avoidance of tactile stimulation, is elevated in several developmental disorders, including autism (Royeen, 1985; Baranek, Foster & Berkson, 1997; Leekam, Nieto, Libby, Wing & Gould, 2007) and Attention Deficit Hyperactivity Disorder (ADHD; Bauer, 1977; Kientz & Dunn, 1997, Mangeot et al., 2001).

[2]The terms sensory sensitivity, sensory responsivity, sensory defensiveness have been used interchangeable throughout the literature, but in this thesis the term 'sensitivity' will be used when referring to both over- and under-sensitivity; 'defensiveness' when referring to a negative reaction (aversiveness or withdrawal to sensory input); and 'responsivity' when referring more specifically to modulation of sensory input.

Symptoms of tactile defensiveness affect many aspects of behaviour and include over-sensitivity to certain clothing textures, food textures, aversiveness to touch from others, and lack of / avoidance of object exploration. In some cases, extreme aversion to some textures has led to avoidance of human contact (Grandin, 1995). Previous studies have gathered evidence suggesting that tactile defensiveness affects many aspects of an individual's life, particularly social interaction, affective ability (Ayres, 1964, 1972, 1979; Royeen & Lane, 1991), and the ability to establish or maintain intimate relationships (Scardina, 1986). Highlighting the effect that tactile defensive behaviours have on the interaction with the environment, Larsen (1982) conducted a study exploring the differences in the responses to the sensory history questions for developmentally delayed children (between the ages of 2 and 6 years) with and without tactile defensiveness. The questionnaire completed by the children's mothers consisted of 102 items, 30 of which had previously been considered as indicative of tactile defensiveness. Of these 30 items, 11 were identified as being able to clearly distinguish between children with and without tactile defensiveness. From these 11 items, five were in the category defined as 'Tactile Response to People', and three were in the category of 'Tactile Response to Environment'. Interestingly, regarding the category of 'Tactile Response to Environment', mothers of children with tactile defensiveness reported that as infants they did not explore and / or manipulate objects. The anecdotal evidence that tactile defensiveness can sometimes result in debilitating behaviours warrants systematic study.

Active exploration of the environment is essential for cognitive development (Piaget, 1954), and for subsequent social behaviour and peer relations (Harlow & Harlow, 1965; Stevenson-Hinde, Zunz, & Stillwell-Barnes, 1980). The importance of the individual's active role in exploration of their environment was also emphasised by Ayres (1972), yet the focus was on the motor function of the individual within the environment, which inhibited this interaction. There is no detailed examination of the debilitating effects of tactile defensiveness on the individual's active exploration. However, although tactile defensiveness and its behavioural consequences are described, there is no research that systematically explores tactile sensitivity in typical and atypical development to better understand unusual tactile responses. Of particular psychological importance, is the lack of exploration by individuals with tactile defensiveness reported in the literature. This thesis aims to explore tactile sensitivity in typical and atypical development to better understand the reported unusual tactile responses observed in individuals with autism. Due to the lack of research focussing on touch, there is a failure to emphasise the importance of touch for development. This chapter will examine the important role that touch has for development and highlight the possible negative consequences that tactile defensiveness could have for typical development.

1.2 TOUCH: *Its fundamental role in development*

The earliest sensory system to develop in the human embryo is the somesthetic system i.e. kinaesthetic and cutaneous processes (Maurer & Maurer, 1988). Kinaesthetic sensitivity refers to spatial position and movement information derived from stimulation of the muscles and joints. Cutaneous sensitivity refers to the sensitivity of the skin to touch, temperature, pressure or pain (Klatzky, Lederman & Reed, 1987). Human fetal studies by Hooker (1952) revealed that from as early as the eighth week of gestation the foetus responds to tactile stimulation. By 13-14th week gestation almost the entire body is sensitive to touch. The fact that the skin is the largest sensory system, matures early and its capacities are among the most basic would lead to the assumption that the somesthetic system plays a fundamental role in development. General embryological principle states that “the earlier a function develops, the more fundamental it is likely to be”, (Montagu, 1986, p.3). However, research has focussed on physical and sensory development with emphasis on visual and auditory perception, and on facial and vocal contribution to social – emotional perception. Despite evidence of the fundamental role that touch plays in development, there is a lack of research focussing on the tactile modality.

1.2.1 *The role of touch in maternal attachment and bonding*

The majority of psychological research exploring the role of touch focuses on the importance of touch in infancy for maternal bonding (e.g. Campbell & Taylor, 1980; Carlson, Fagerberg, Horneman, Hwong, Larsson et al., 1978; and De Chateau, 1976) and attachment (e.g. Bowlby, 1969, 1980; Ainsworth, 1967, 1969). Other research on the importance of touch has examined the role of touch in mother-infant interactions, using still-face methods (e.g. Field, Vega-Lahr, Scafidi & Goldtein, 1986; Stack & Muir, 1990; Tronick, 2003) and non-still face methods (e.g. Roedell & Slaby, 1977; Roggman & Woodson, 1989), and touch as communicating emotion (e.g. Montagu, 1986; Landau, 1989).

Research into the importance of touch for non-human species is well-established (e.g. Montagu, 1986; Denenberg, 1962, 1969). Harlow's (1959) work on maternal sensory deprivation in rhesus monkeys demonstrated the importance of physical contact in the development of social attachment. Contradicting conventional belief at the time, that during the feeding process infants formed social attachment bonds with their mothers, Harlow (1958) demonstrated that the source of tactile contact was more important than receiving nourishment in establishing a social bond. Observations revealed that those monkeys reared on 'wire' mothers displayed stimulus-seeking behaviours and could not tolerate being in an unfamiliar environment, i.e. would not explore the objects and the room. By comparison, monkeys reared on 'cloth' mothers freely explored the unfamiliar environment. Harlow's work emphasised the importance of tactile stimulation in the development of secure emotional attachment, which enables crucial exploration of the infants' surroundings.

In support of the role that tactile stimulation plays for the infants' exploration, Seay, Hansen and Harlow (1962) demonstrated that all the infants' exploratory behaviours immediately ceased when tactile contact to its mother is denied, even if the mother remains in visual contact with the infant, emphasising the crucial role that tactile contact has on early exploratory behaviour. In addition, Harlow, Harlow and Suomi (1971) demonstrated that monkeys reared in single-cages developed unusual behaviour patterns including self-clasping and idiosyncratic patterns of repetitive stereotyped activities. When introduced to other monkeys they displayed no exploratory or play behaviour, but instead withdrew from social contact. It is evident from these findings that lack of the appropriate amount and type of tactile contact during early development, which results in abnormal behavioural patterns, can have detrimental effects on the normal social development of the infant monkey i.e. exploration is essential for the development of the infants' subsequent social behaviour and peer interactions, (Harlow, Harlow, 1965; Stevenson-Hinde & Harlow, 1975). The findings exemplify that stimulation, provided through tactile contact appears to be crucial for normal development to take place.

Levine (1956,1960; Stanton & Levine, 1990) found that rats, not handled during infancy, could not tolerate stress and were afraid to explore new environments and over-reacted to unfamiliar situations. In human infants, Ainsworth (1963, 1967) demonstrated the crucial role of tactile stimulation in the development of mother-infant attachment patterns. Ainsworth discovered that securely attached infants, who had received the appropriate amount and type of tactile stimulation, freely explored their unfamiliar surroundings, whereas infants who were classified as being anxiously attached to their mother explored little and remained close to their mother. In support of these results, Ainsworth, Blehar, Waters and Wall (1978) also demonstrated that secure positive attachment was related to higher levels of touch between mother and infant.

Research with institutionalised infants who were sensory deprived, revealed that the lack of tactile stimulation resulted in appalling behavioural and developmental effects (Provence & Lipton, 1962; Spitz & Wolf, 1946). It was argued by Casler (1961, 1968) that the degree of sensory stimulation was a crucial contributing factor to the development and behaviour of institutionalised infants. In addition, Cermak and Groza (1998) highlighted the sensory processing problems in post-institutionalised children, with specific hypersensitivity to touch, movement, sight, sound and smell. Ainsworth (1962), in contrast argued that the lack of intimate relationships was responsible for the behavioural problems exhibited by institutionalised infants. Either explanation gives support for the crucial role that tactile contact plays in development.

These findings may be comparable to the negative effects of tactile defensiveness mentioned earlier. It could be suggested that tactile defensiveness may lead to similar behavioural outcomes, affecting the ability to form a secure attachment. Tactile defensiveness has been shown to result in a lack of exploration and withdrawal from social engagement (Larsen, 1982). Multiple large-scale studies on attachment and social development have demonstrated the link between insecure attachment and difficulties in social abilities, (Greenberg, 1999). Other studies have found a significant relationship between sensory sensitivity and adult attachment style, with sensory sensitivity related to relationship anxiety, and sensory seeking related to secure adult romantic attachment (Jerome & Liss, 2005). Yet, there is no research investigating the relationship between tactile defensiveness and attachment patterns with the mother. Most recently however, there is some literature suggesting that research needs to explore the relationship between sensory reactivity (responsivity) and early attachment and cognitive development (Tavassoli, et al. 2018). It could be proposed that a lack of tactile stimulation (handling / rocking) from the mother as infants (due to the infants' intolerance to touch) results in insecure attachment patterns between mother and infant. In turn this could exacerbate problems with exploration and social interaction.

In view of tactile defensiveness, insecure attachment would not be the result of low levels of sensitivity /responsivity of the caregiver / mother (Ainsworth, Blehar, Waters & Wall, 1978), but due to the infants' intolerance of being held / touched. Although tactile deprivation is the underlying outcome, there are two different means through which deprivation occurs, i.e. lack of sensitivity of mother or the infants' inability to tolerate touch. Both could result in similar negative consequences for the infant, however disentangling the relationship between all these variables would be difficult.

1.2.2 *Touch and its regulatory function in development*

Further research into the role of touch in non-human species has indicated that physical contact plays an important regulatory function in development, i.e. regulating growth (Kuhn & Schanberg, 1998), regulating physiology and behaviour (Hofer, 1998) and regulating stress response (Levine, 1956, 1960; Levine & Stanton, 1990). Møllgaard et al. (1971) demonstrated that a lack of stimulation hinders development whereas sensory stimulation, through increased handling and variation of experience enhances development, indicated by heavier cerebral cortex, increased thickness of cortical tissue and a greater number of glial cells.

Brazelton's (1990) observations of the neonate revealed that touch in early infant development can regulate physiological and behavioural reactions. Fogel (1997), in support of these findings, demonstrated that touch can help control the state of arousal in the infant, where arousal refers to the infant's ability to maintain alertness in response to activation. The ability to regulate arousal state is critical to enable the individual to attend to sensory input and successfully engage in an adaptive manner to their environment (De Gangi, 1991; Dunn, 1997). Individuals with sensory modulation disorders (including tactile defensiveness) are easily over-stimulated and become overwhelmed and stressed with sensory input or can be under-stimulated resulting in decreased arousal and latency in responding to their environment. If the individual becomes over-stimulated (high arousal state) their actions may be defensive and / withdrawn and they may not tolerate tactile stimulation. By comparison, under-stimulated individuals require additional sensory input (Williamson & Anzalone, 2001). It is evident that the role of touch is important in aiding regulation of arousal levels in sensory modulation disorders.

Korner and Thompson (1972) found that tactile contact was effective in soothing infants. In support Byrne and Horowitz (1981) found that rocking the infant helped to calm distressed newborns. By comparison, there are infants who display problems in sleeping, feeding, arousal and do not tolerate being held / cuddled. Referred to as regulatory disordered infants (De Gangi, Di Pietro, Greenspan & Porges, 1991), these 'fussy' babies are at high risk of later developing perceptual, sensory integrative, language and behavioural difficulties (De Gangi, Porges, Sickel & Greenspan, 1993). These infants often display hyper and hypo-sensitivity to sensory stimuli, much like individuals with Sensory Integration Dysfunction (SID). De Gangi, Sickel, Wiener & Kaplan (1996) found that regulatory disordered infants that were not treated exhibited numerous perceptual, attentional, emotional, behavioural problems, including tactile defensiveness, gravitational insecurity and under-responsivity to movement at 3 years old. Treatment consisted of 12 weeks intervention focussing on parent-child interactions, and sensory integrative therapy, which involved desensitising, organising sustained attention and promoting self-calming. In addition to not being able to be soothed through holding / rocking these infants have difficulty tolerating touch and display inability to explore objects through touch. Similar behaviour has been observed in infants who are anxiously attached to their mother (Ainsworth & Bell, 1970), and sensory deprived institutionalised infants (Provence & Lipton, 1962). Although these negative effects are evidenced there is little to no research on the impact that regulatory disorders have on parent-child relationships, and the effect on the infants' exploration of their environment.

1.2.3 *The importance of active touch in exploration*

Research reviewed on the role of touch in maternal bonding, attachment, and arousal regulation views touch primarily as promoting social and emotional relationships, exploring the behavioural and physiological changes in the infant induced by touch. In this sense tactile contact is referred to as 'social touch'. In the majority of situations examined, touch is passively received by the infant with little emphasis on the role of the infant's active exploration of the environment in development, i.e. the role that touch plays in guiding perception and exploration of the external environment.

Information of the external world does not passively arrive, but it requires motion that is kinaesthetically sensed to receive the complex patterns of cutaneous stimulation. Early research by Katz (1925) and Revesz (1950) emphasised the important role that active manual activity played in haptic perception, i.e. the active use of touch to seek out information. Touch in this exploratory form, Gibson (1962) referred to as ‘active touch’, by which touch enables us to receive information about objects and surfaces in the external environment. By comparison, Gibson referred to ‘passive touch’ as a means to bring to our attention to information; stimulation over which the immobile observer has no control. Gibson (1962) demonstrated the superiority of active touch over passive touch in object perception through a series of experiments, confirming the importance of movement in discrimination during haptic perception.

Through active tactile (haptic) exploration infants’ gather information of the external environment. Piaget (1953, 1954) suggested that development was a dynamic process between the child and the environment, in which object manipulation is critical for the child to learn about objects and their environment. Piaget proposed that is was during active manipulation of objects that mental activity occurs. Piaget (1953) described three periods of development, 1) sensori-motor, 2) pre-operational, and 3) operational. The sensori-motor phase encompasses the first two years of life and describes 6 stages of increasingly complex manual activity, finally reaching the transition stage between sensori-motor and preconceptual thought. Piaget’s theories emphasise the critical role that active exploration plays in the development of early cognition. Piaget and Inhelder (1956) suggested that early tactile exploration is an essential foundation for future cognitive development. In an early cross-modal study, Piaget and Inhelder presented several familiar objects to children aged 2-7 years old. Their task was to identify the objects through tactile manipulation alone. Findings revealed that with increased developmental age, there was an incremental increase in active systematic exploration and increased ability to distinguish between complex forms, thus greater recognition of objects. In other cross-modal studies, Rose, Gottfried and Bridger (1978), and Gottfried and Rose (1980) revealed that one-year old infants, after only 30secs of handling, can recognise an object previously felt by touch alone. The study demonstrated that infants effectively use active touch to explore their surroundings. Further evidence for the importance of active tactile activity was demonstrated by Fraiberg’s (1977) study exploring recognition in blind 5-8 month old infants. Infants actively explored the mothers’ and fathers’ face, expressing familiarity with what they were encountering. The results give convincing evidence that infants, using their fingers, could actively discriminate between familiar and non-familiar faces.

Emphasising the importance of infants' active exploration of the environment, Gibson (1966) proposed that infants were more capable at birth than originally suggested by Piaget. Active exploration enables the infant to learn about particular properties of objects, which Gibson referred to as 'affordances', such as texture, weight, shape and substance. According to Gibson infants achieve this through coordinated action systems. With increasing actions, new affordances are learnt, thereby learning becomes a reciprocal process between the infant and its environment (Gibson, 1988). In comparison to typically developing infants, parents of children with tactile defensiveness reported that as infants they did not explore or play with objects (Larsen, 1982). It could be proposed that tactile defensiveness in early infancy hindered the child's ability and motivation to explore his environment, which led to later behavioural problems. Further research is needed to evaluate this suggestion.

1.2.4 *Exploratory procedures in manual exploration*

Underlying the research on active and passive touch is the focus on hand movements (Heller, 1991). Through careful observation of hand movements, Lederman & Klatzky (1987) investigated the strategies used to manipulate objects, defined as 'exploratory procedures' (EP's). Each of the six identified exploratory procedures is linked to the perception of a specific object property, such as the Lateral Motion EP (rubbing finger across surface) to perceive texture, the Pressure EP (squeezing, poking objects) to determine hardness, and the Enclosure EP (holding / grasping object) to perceive the shape, size, and volume of an object. However, the EP's proposed by Lederman and Klatzky (1987) only relate to individuals with mature haptic abilities, and whose manual exploration is not restricted in any way. Infants cannot motorically execute all the movements described by Lederman and Klatzky's exploratory procedures.

Within the first year of life infants' exploratory procedures develop from simple reflexive behaviours to well-integrated and coordinated behaviours of reaching and grasping. Piaget (1953) laid the foundation for research into early exploratory / haptic behaviour with previously mentioned description of the sensori-motor period. Extending Piaget's work, Gibson (1988) proposed that there were three phases of exploratory development in the first year of life, which enabled the infant to discover new affordances through increased ‘action systems’. In the first period (0-5 months) Gibson describes the infants’ ‘immature and unskilled’ exploratory skills. During the second phase (2-9 months) exploratory skill becomes increasingly coordinated and allows the infant to discover new affordances. According to Gibson the final phase (9 months +) is characterised by independent locomotion, referred to as ‘ambulatory exploration’; behaviour is self-controlled and enables the infant to learn new kinds of exploratory activity.

A more recent model of early exploratory abilities was outlined by Bushnell and Boudreau (1991), which describes the developmental sequence of manual behaviours during infancy, making explicit links to Lederman and Klatzky’s (1987) exploratory procedures (EP’s). The three phases proposed by Bushnell and Boudreau’s model include a detailed account of manual behaviour during infancy. Phase one (0-4 months) consists primarily of oral exploration, considered a separate modality to manual exploration. ‘Clutching’ behaviour observed during phase one is described similarly to the ‘Enclosure EP’ of Lederman and Klatzky. In this phase, object properties of texture, weight and shape are not expected to be perceived, but hardness and texture can be detected through oral exploration. Phase two (4-9 months) is characterised by one-handed manual activity, involving repetitive and banging behaviours. There is an increase in the number of manual behaviours observed, which are comparable to the number of EP’s described by Lederman and Klatzky. By phase three (9/10 months) infants use both hands to manipulate the object, which enables exact shape to be determined through the ‘Contour tracing EP’. Although Bushnell and Boudreau’s (1991) model of the development of manual behaviour during infancy was developed from a pattern of typical development, is has been used as a reference for children with multiple disabilities (McLinden &McCall, 2002).

Since vision plays a crucial role in the development of haptic exploration (Pehoski, 1995), visual impairment restricts the infants’ engagement in the environment, decreases stimulus value, and reduces the infants’ known impact on his/her environment (Warren, 1994). The importance of visual feedback in action patterns was demonstrated by Ross & Tobin (1997) in their study of independent spoon use in blind children. Visual feedback enables the child to know when the spoon has food in it and indicates how the spoon should be used. Research suggests that visually impaired infants show a general delay in the development of early haptic abilities (e.g. Fraiberg, 1977). Visual impairment is a barrier to learning through touch, as is the selective response to touch in individuals with tactile defensiveness, who react negatively to tactile stimulation through passive and active touch.

Despite the vast array of evidence supporting the important role of touch in development, and the evidence suggesting debilitating effects of tactile defensiveness on exploration and later social and emotional development, there is a lack of research investigating the possible causes of unusual tactile response.

1.3 Sensory abnormalities in atypical development and autism

Although sensory symptoms can occur in the absence of developmental disorders, research has evidenced abnormal processing of sensory information in individuals with Pervasive Developmental Disorders (PDD), Autism, Aspergers and Attention Deficit and Hyperactivity Disorder (ADHD, e.g. Ayres, 1979; Ayres & Tickle, 1980; Baranek, Foster & Berkson, 1997, Blakemore et al. 2006; Mangeot et al., 2001). The field of psychology has also seen an increase in research on sensory sensitivities is autism, (e.g. Blakemore et al., 2006; Goldsmith Van Hulle, Arneson et al., 2004; Guclu, Tanidir, Mukaddes & Unal, 2007; Rogers, Hepburn & Wehner, 2003; Talay-Ongan & Wood, 2000). Sensory abnormalities have been reported in the literature from as early as the 1940's. Kanner (1943), in his early description of autism, observed unusual responses to sensory stimulation, such as attention to parts rather than the whole and apparent differences in sensitivity to external sensory stimuli. Early clinical descriptions of autism refer to hypersensivity to tactile, auditory and visual stimuli, and a tendency to ignore pain and cold temperature (Ornitz et al., 1970; Rutter, 1966). Bergman and Escalona (1949) conducted a case study of five children who displayed marked sensory abnormalities across all sensory modalities, including examples of vestibular sensitivity, as well as specific texture preferences and aversions of materials and foods. Yet, compared to language development, social functioning and cognitive functioning, the area of sensory symptoms has been understudied (Goldstein, 2000). Even though over the last 50 years autobiographical literature on autism has emphasised sensory processing difficulties (e.g. Grandin & Scariano, 1986; Williams, Costall & Reddy, 1999; Gerland, 2003), the research orientation in the field of autism has focussed on abnormalities in social communication and cognition, specifically impairments in joint attention (e.g. Loveland & Landry, 1986; Charman, et al. 1997; Charman, 2003; Dawson et al., 2004), affective pragmatic (e.g. Baron-Cohen, 1988; Bishop, 1989; Ozonoff & Miller, 1996), and theory of mind impairment (e.g. Baron-Cohen, 1990; Happé & Frith, 1995; Baron-Cohen, 2000). More recently however, there has been an increase in research focusing on the unusual sensory responses observed in atypical development, specifically in autism (O'Neil & Jones, 1997; Behrmann & Minshew, 2015; Kern et al., 2006; Ben-Sasson et al., 2009). Most of this research has focused, either on prevalence of overall sensory symptoms in autism (Rogers, Hepburn & Wehner, 2003; Leekam et al. 2007; Wiggins, Robins, Bakeman & Adamson, 2009), or specific sensitivities in visual perception (Dakin & Frith, 2005; Behrmann, Thomas & Humphreys, 2006) and auditory perception, such as pitch sensitivity (Bonnel, Mottron, Peretz & Trudel, 2003), but there is a lack of research into unusual tactile processing reported anecdotally in the literature. The acknowledgment of the prevalence of unusual sensory response has led to the inclusion of sensory abnormalities as part of the core diagnostic criteria for ASD in the newly revised diagnostic manual (DSM-5; American Psychiatric Association, 2013), emphasising the role of sensory processing in understanding autism. The criteria acknowledge that the sensory abnormalities could present as either hyper or hypo responsiveness to sensory input. Sensory processing difficulties are divided into two main types of responsivity – hypo and hyperresponsivity to sensory stimuli in social and non-social contexts compared to typically developing individuals and developmentally delayed. Hypo-responsivity refers to an underarousal (high threshold) to sensory stimulation, which can result in sensory seeking behaviour. In contrast, hyper-responsivity refers to an over-arousal (low threshold) to sensory stimulation which can result in aversion to social touch, avoidance of certain textures and a lack of attention to novel objects (Baranek et al. 2006; Dunn, 1997).

1.3.1 *Prevalence of sensory abnormalities in autism*

Autism Spectrum Disorder (ASD) is a disabling neurodevelopmental condition, which has a complex heterogenous biological etiology (Betancur, 2011). Core diagnostic symptoms include persistent difficulties in social communication and interaction, restricted and repetitive patterns of behaviours, interests or activities and hyper – or hyporeactivity (responsivity) to sensory input or unusual interests in sensory aspects of the environment, (e.g. indifference to pain / temperature, adverse response to specific textures or sound, excessive smelling or touching of objects, visual fascination with lights or movement; DSM-5, 2013). The diagnosis of autism is relatively stable over time. Chawarska, Klin, Paul, Macar and Volkmar (2009) found 100% diagnosis of those children reassessed at 46.9 months. Most of the research indicates a greater preponderance of males over females who are diagnosed with ASD (approximately 4:1). However, some studies indicating a higher ratio of between 6.54:1 to 12.07:1 for autism and Asperger syndrome respectively (Whiteley, Todd, Carr & Shattock, 2010).

Sensory processing difficulties in autism occur in multiple forms, across all modalities (Kern et al., 2006, Harrison & Hare, 2004). Dunn (1997) proposed a model of sensory processing of neurological thresholds. The model describes four patterns of sensory processing dysfunction: Low Registration, Sensation Seeking, Sensory Sensitivity and Sensation Avoiding. These patterns of dysfunction in sensory processing are classified according to individuals' behavioural response to stimuli. To understand the role played by sensory processing in autism, Dunn (2007) proposed that further systematic exploration of sensory processing differences in children with autism is required. It is now widely recognised that differences in sensory processing differentiate individuals with autism from typically developing individuals (e.g. Kientz & Dunn, 1997; Iarocci & McDonald, 2006; Rogers & Oronoff, 2005; Tomcheck & Dunn, 2007; Watling, Dietz & White, 2001). Prevalence rates of sensory abnormalities in autism vary across studies, from 100% auditory processing difficulties (Greenspan & Wieder, 1997), 53% disturbed by noises (Volkmar, Cohen & Paul, 1986), and 30% auditory hyper responsiveness (Baranek, Foster & Berkson, 1997). More recently, Leekam et al. (2007) reported 90% prevalence of sensory abnormalities in children with autism, in multiple sensory modalities. In addition, sensory abnormalities appear to persist throughout development (O'Neill & Jones, 1997). Crane, Goddard and Pring (2009) reported that sensory abnormalities present in adults diagnosed with autism, remain present throughout the lifespan, illustrating the persistence of sensory abnormalities in individuals with autism. Talay-Ongon & Wood (2000) argue that sensory abnormalities are central to the condition of autism.

Sensory abnormalities are also evident in other clinical populations, such as ADHD (Ermer & Dunn, 1998; Mangeot et al., 2001; Reynolds & Lane, 2008), Fragile X Syndrome and Developmental Disorders (Rogers, Heburn & Wehner, 2003; Baranek, David, Poe, Stone & Watson, 2006). Earlier studies have found contradictory evidence for significant group differences in sensory symptoms across clinical populations. Wing and Gould (1979) found similar rates of sensory symptoms for blind and deaf children compared to children with autism. In addition, Miller, Reisman, McIntosh and Simon (2001) using parent reports, found no significant difference between Fragile X, SMD (severe multiple disabilities) and autism groups on overall sensory symptoms. In comparison, recent studies have shown significant differences in the prevalence of sensory symptoms across clinical groups. Leekam et al. (2007) reported group differences in total number of sensory symptoms between children with autism, DD (developmental delay), language impairment and typically developing children. Significant differences were also found in specific domains of smell, taste and vision. These findings are confirmed by Wiggins et al. (2009) who found that at first ASD assessment, children with autism had more sensory impairments than individuals with developmental delay (DD); specifically in tactile, taste and smell sensitivity, and auditory filtering. These results are consistent with Kientz and Dunn (1997) who reported more severe and more frequent sensory symptoms in children with autism. It has also more recently been reported that sensory over-responsivity is positively correlated to autistic traits (Tavassoli, Miller, Schoen, Nielson & Baron-Cohen, 2013). There are numerous reports of unusual sensory perceptual processing in autism, yet the mechanisms underlying these sensory phenomena and the possible relationships between sensory abnormalities and the effects on development are not well understood (e.g. Gogolla, Takesian, Feng, Fagiolini & Hensch, 2014).

Ayers and Tickle, (1980) stated that “autistic children represent a heterogeneous group with certain symptoms in common – one of which is disturbance in sensory processing, which may vary from child to child, and reflects poor modulation or inadequate registration of incoming stimuli characterised by over or under reaction to sensory input”, pg. 375. Although it is anecdotally claimed that individuals with Autism and Asperger Syndrome are hyper- / hypo-sensitive to touch, there is lack of empirical research on the sensitivity to tactile stimulation in autism, particularly with regards to withdrawal from or fascination with certain textures. Since sensory symptoms are prevalent in autism and other developmental disorders, it is important to include other clinical groups in research to be able to determine which findings are specific to autism alone. Therefore, studies in the thesis include ADHD clinical comparison group. Research has indicated that individuals with ADHD experience sensory processing difficulties (Ghanizadeh, 2010), and have found a relationship between hyperactivity and sensory deficits in individuals with ADHD (Yochman, Parush & Ornoy, 2004; Mangeot et al., 2001). Therefore, individuals with ADHD make a good control group to explore whether unusual tactile sensitivities are specific to ASD.

1.4 Explanations of tactile defensiveness

Previous literature, on a variety of clinical populations, provides evidence of the presence of sensory integrative deficits, including deficits in tactile perception, however these behaviours had not been specified as being 'components of tactile defensiveness' (Larsen, 1982). For example, Prechtl (1963) observed two distinct syndromes of minimal brain dysfunction, i.e. hypokinetic and hyperexcitable, in newborns. Hypokinetic infants displayed behaviours that were described as 'hypotonic, apathetic and drowsy'. It was also noted that these infants responded weakly to stimulation. In contrast hyperexcitable infants were hypertonic, displayed exaggerated responses and appeared to have a lower threshold to sensory stimulation. Thus, the behaviour of hyperexcitable infants has a marked resemblance to tactile defensive behaviour.

An early explanation of tactile defensiveness was proposed by Head (1920; as cited in Ayers, 1964). The reflexive, protective (flee-or-fight) response to tactile stimuli is hypothesised to be indicative of the function of the phylogenetically older system-the 'protopathic system' (Head, 1920). This protective/ defensive behaviour results in distractibility (over alertness / hyperactivity), expressed in flight-like behaviour and a tendency toward negative affect. According to Head (1920) the protopathic system forms part of the dual cutaneous system. The protopathic system is responsible for protecting, defending or warning the organism against potential harm, whereas the epicritic system, which is superimposed on the older protopathic system is higher functioning and is responsible for discrimination of tactile stimuli. Both systems can detect pain, however, the protopathic system is particularly concerned with pain, which often results in motor responses of repulsion. Head proposes that a function of the epicritic system is to control and monitor the sensibility of the protopathic system. Evidence of different sensory disorders lends support to the hypothesised struggle between the two systems of sensation. For example, Head described certain kinds of dysfunction (resulting from brain injury), which caused individuals to respond to pain and other tactile stimuli with excessive affective and sometimes excessive movement reactions. In other cases, dysfunction affected discriminative tactile perception and movement due to the lack of appreciation of joint positions. Head claimed that although the higher functioning systems dominated the lower systems, they depended upon their existence for the fulfilment of their own functions.

Larsen (1982) presents two hypotheses on the underlying neurophysiological mechanisms of tactile defensiveness. Based on the dual components of the tactile system, the first hypothesis proposes that the spinothalamic and lemniscal systems are responsible for producing tactile defensive behaviour. The spinothalamic or protective system interprets incoming stimuli as being potentially threatening, and therefore responds with movement, alertness and a high degree of affect. According to Semmes (1969) the lemniscal or discriminative system aids cognition in the interpretation of temporal and spatial qualities of stimuli. The lemniscal system is proposed to have an inhibitory effect on the function of the protective system. The spinothalamic system has been likened to Head's (1920) protopathic system, and the lemniscal to the epicritic system. According to Ayres (1964), under certain circumstances and with particular individuals, the two systems either never attained their balance or lose their balance resulting in the protective system dominating the discriminative system. This results in avoidance and/ or aversive reactions to certain stimuli, which is typical of tactile defensive behaviour. Therefore, the underdeveloped discriminative (lemniscal) subsystem does not mature properly, due to insufficient stimulation, and thus the child is deprived of spatial and temporal qualities of tactile stimuli, (Ayres, 1964). This results in the child having a lack of information about his/her environment. The question remains to what effect would such a deficit have on the child's interaction with the environment, specifically their object exploration and manipulation, and consequently their cognitive and social development. In support of this hypothesis, McCracken (1975) carried out a study exploring whether children with learning disabilities would display a greater degree of tactile deficiency. Results indicated that compared to normally developing children of the same age, children with learning disabilities performed significantly lower on tests of graphesthesia, finger identification, manual form and the perception of simultaneous stimuli. More interestingly, children who displayed tactile defensive behaviours showed greater dysfunction of manual form (i.e. the recognition of objects through touch alone) and graphesthesia, as compared to those without tactile defensiveness. Both tests require the discrimination of object form and the spatial and temporal qualities of stimuli, and require the child to have a repertoire from previous experience of forms and shapes. Therefore, the results lend support to the theory that tactile defensiveness is the result of an underdeveloped discriminative (lemniscal) system, i.e. these abilities in discrimination are mediated by the medial lemniscal subsystem.

The second hypothesis is based on the interconnections between the somatic afferent system and the central nervous system, particularly the reticular activating system. The central nervous system controls the amount of sensory information that is filtered or inhibited to ensure efficient functioning, thereby allowing only relevant sensory stimuli to filtrate at any given moment (Luria, 1973). It is suggested that higher-level central influences may cause an imbalance in descending mechanisms of the reticular system. Therefore, the tactile defensive child experiences a lack of or predominance of the excitatory component, which results in either excessive or insufficient inhibition. Consequently, this would lead to an inability to respond appropriately to or suppress differentially the stimuli within the perceptual field. This imbalance therefore reduces the ability to perceive incoming stimuli from tactile and other sensory modalities. It is proposed that the type of receptor alone does not determine the subjective experience but is dependent on the adequate functioning of mechanisms with the central nervous system. Therefore, it is suggested that such an imbalance in the central descending control mechanism may account for the emotional liability and variation in degree of tactile defensive reactions at any one moment within a child.

Royeen and Lane (1991), accounting for the evidence that individuals can either over-respond or under-respond to tactile stimuli, propose a circular relationship between under- and over-responsiveness. In this relationship the individual over-responds to the stimulus until overload occurs and then shuts down; associated with under-responsiveness. The model differentiates between those individuals who consistently over-respond, those who consistently under-respond, and the group who either over / under respond depending on the situation or stimulus. Based on this conceptualisation, Royeen and Lane (1991) propose that there is a clear distinction between tactile defensiveness - exhibited by individuals who consistently over-respond, and poor tactile discrimination – associated with under-responsiveness and an inability to discriminate between objects and their surface properties. However, due to limited research and the fact there are still individuals who either over / under-respond, there is insufficient evidence to conclude that they are two separate expressions of Sensory Modulation Dysfunction.

The theories specified above have been used to describe tactile defensiveness within the conceptual framework of sensory modulation dysfunction in the field of Occupational Therapy. However, more recent physiological and anatomical research has found that instead of separate discrete channels that convey cutaneous sensory information, sensory integration begins at subcortical levels (Abraira & Ginty, 2013).

1.4.1 *Cutaneous mechanoreceptors and tactile discrimination*

The somatosensory system is the primary sensory modality responsible for proprioceptive processes and cutaneous sensitivity. Proprioception refers to the monitoring and control of limb position and limb movement, and cutaneous sensitivity refers to the process of sensory inputs arising from the skin. For the purposes of this thesis, the focus is on cutaneous sensitivity. The cutaneous submodalities have traditionally been divided into four channels; tactile, thermal, pain and itch. The tactile submodality of the somatosensory system is responsible for the perception of pressure, vibration and texture, the perception of which relies on specific receptors (Abraira & Ginty, 2013).

Cutaneous sensory neurons (receptors) differ in conduction velocity, adaptation properties and cell body size, and are classified as either Aβ fibers, Aδ fibers or C fibers. Aδ and Aβ and sensory neurons have medium to large cell body sizes with intermediate to rapid conduction velocities, whereas C-type sensory neurons have the smallest cell body size and slowest conduction velocity. Aδ and C-Fibers are proposed to be nociceptors, i.e. receptors responding to harmful or potentially harmful mechanical, heat or cold stimuli. Aβ fibers have low mechanical thresholds and respond to weak mechanical force applied to the skin, thus referred to as light-touch receptors or Low Threshold Mechanical Receptors (LTMRs). These Aβ fiber associated LTMRs can be further differentiated by the cutaneous end organs they are associated with, and their preferred stimuli, i.e. Pacinian corpuscles, Ruffini endings, Meissner corpuscles and Merkel’s discs. Each of these LTMRs respond to unique features of tactile stimulation and are either slowly adapting (SA) or fast adapting (FA) receptors, exhibiting maintained firing with contact or firing only at the initial and final contact of mechanical stimuli respectively. Merkel cell and Ruffini are slowly adapting receptors, with Merkel cells responding to indentation (spatial discrimination and stimulus position) and Ruffini responding to skin stretch (change in hand and finger shape and direction of hand movement). Recent research in mice has found that when

Merkel cells fail to develop, the mice can no longer detect textured surfaces (Maricich, Morrison, Mathes & Brewer, 2012; cited in Abraira & Ginty, 2013), evidencing the role of LTMRs in texture discrimination. Meissner corpuscles and Pacinian corpuscles are fast adapting receptors. Meissner corpuscles are particularly sensitive to stimuli moving across the skin and low frequency vibration. Pacinian corpuscles are extremely sensitive to high frequency vibration of objects haptically explored in the hand.

There are three somatosensory paths that convey tactile information about mechanical, thermal and painful stimuli. These are located in the dorsal columns and spinothalamic tracts. Primary tactile afferents ascend up the spinal cord forming the dorsal columns. They then establish their first synapse with neurons at the medulla. This forms a tract – the medial lemniscus. Secondary tactile afferents, from both the thin outermost layer of the dorsal horn and second layer of the dorsal horn, cross to the opposite side of the spinal cord to ascend in the spinothalamic tract. The spinothalamic tract then ascends the spinal cord to the midbrain, from where the lemniscus tract and spinothalamic tract enter the thalamus together. The dorsal column tract (lemniscus) is responsible for transmitting tactile information of tactile, pressure, vibration and proprioception, and the spinothalamic tract is responsible for pain and temperature. The third-order tactile afferents, referred to as thalamocortical afferents, travel from the thalamus to the cortex and convey all the signals to the primary somatosensory cortex. From here sensory information from contralateral body surfaces are body-mapped (somatotopic map; Madjian, Gotschalk, Patel, Detre & Alsop, 1999; cited in McGlone & Reilly, 2010). In this mapping, the hand and lips are overrepresented relative to the trunk and arms (Penfield & Rasmussen, 1952). The three spinal cord pathways differ in receptors, their target brain areas and the level of cross-over within the central nervous system. Although it is presumed most afferent information is conveyed through separate tracts as described above, there is some cross over of information between tracts (McGlone & Reilly, 2010).

Therefore, given the more recent evidence presented above several different physiological processes could be involved in tactile defensiveness.

1.5 Assessing sensory defensiveness

This reactive response to sensory information in autism is observed across all sensory modalities and is referred to as *sensory defensiveness*, under the umbrella term of sensory modulation disorders (mentioned earlier). However, even though sensory modulation disorders have frequently been referred to there is little statistical evidence to support its existence. Until recently, diagnosis has been made purely on observation and the child's sensory history. Ayres' analytical work rarely included evidence of modulation disorders, and even then, only of *tactile defensiveness.* Research by Dunn (1979; 1999) has provided preliminary foundation of information about the nature of sensory modulation disorders. More recent findings by Lane et al. (2010) support Dunn's (1997) model of sensory processing and the sensory quadrants which categorise behaviours in terms of modulation and neurological thresholds. Lane and colleagues reported that there are three distinct parent-reported sensory processing subtypes observable in a group of children with autism. The three subtypes were described as: sensory modulation with movement sensitivity (SMMS), sensory modulation with taste/smell sensitivity (SMTS) and sensory-based inattentive seeking (SBIS). Consequently, Dunn (1999) designed the Sensory Profile, an assessment tool to identify sensory modulation disorders. The Sensory Profile is used to formulate the four quadrants of sensory processing; Low Registration, Sensation Seeking, Sensory Sensitivity and Sensation Avoiding (Dunn, 1997). After reviewing available methods for evaluating sensory integrative abilities in children, Dunn (1994) concluded that most of the assessments did not examine performance within natural contexts. That is, current assessment tools are based on the performance of isolated tasks in unrealistic settings, and therefore therapists are left to infer how behaviour relates to daily activity in order to plan intervention for actual life settings. Therefore, the Sensory Profile (SP) attempts to address this issue by requesting information on performance within natural contexts.

Recent literature, using the Sensory Profile has found that the measure can significantly differentiate between clinical groups on sensory symptoms. For example, using the Short Sensory Profile, Rogers, Heburn and Wehner, (2003) compared children with autism, Fragile X Syndrome, DD and typically developing children and found that children with autism and those with Fragile X Syndrome had significantly more sensory symptoms than the other two groups, but the autistic groups did not differ significantly from individuals with Fragile X Syndrome. In addition, another questionnaire, the Sensory Experiences Questionnaire (Baranek et al., 2006) significantly discriminates sensory features in children with autism, DD and typically developing children. Results found that 69% of children with autism displayed significantly higher sensory symptoms than the two other groups.

Since the theory of sensory integration is firmly situated in the field of occupational therapy, its main purpose is to therefore identify dysfunction and develop appropriate intervention to ameliorate difficulties identified. There is little emphasis however, on the implications that such unusual sensitivities and behaviours have on cognitive, social and emotional development. Instead there is more focus on the organism-environment interaction and its role in brain development and function, (Ayres, 1972). For example, the literature describes and specifies the symptoms / phenomenon of tactile defensiveness, but the content remains at the descriptive level, i.e. there is no investigation into the impact that tactile defensiveness has on active exploration, on social engagement or peer relations. Although Ayres cited the psychologist Harlow's (1958) work on sensory deprivation, her focus was on the effects that environmental deprivation has on brain development and behaviour, with no emphasis on the crucial role of touch and how sensory deprivation effects the development of emotional bond to the mother and thereby the infant's ability to explore their environment.

The importance of treating sensory defensiveness is emphasised by Wilbarger and Wilbarger (1991), who verify that sensory defensiveness is particularly disruptive to an individual's life through a tendency to negatively react to sensory stimulation usually regarded as harmless or to completely withdraw from certain stimuli / situations. For these reasons it is argued that sensory defensiveness should be of primary focus in intervention (Wilbarger & Wilbarger, 2002). Despite literature highlighting the importance of tactile function in development and emphasising the impact that tactile defensiveness can have on various aspects of daily activity, Larsen (1982) reported that there was no objective way to evaluate dysfunction in infancy or when the infant was developmentally slower than normal, i.e. there is a lack of assessment tools to identify tactile defensiveness. Therefore, to determine the presence or absence of tactile defensiveness therapists have to rely on their clinical expertise and subjective observations. Interviews with the mother and subsequent observations allow for additional information on the child's sensory history to be gathered. Although clinical observations are the primary means of identifying tactile defensive behaviour, Bauer (1977) designed the Tactile Sensitivity Behavioural Response Checklist to measure the frequency of such responses during the administration of subtests of the Southern California Sensory Integration Tests, (S.C.S.I.T, Ayers, 1979). However, this is not an objective measure, but serves as an additional observation of behaviour indicative of tactile defensiveness.

It is also important to note that most studies in the field of occupational therapy have used one of two assessment tools, either the Southern California Sensory Integration Test or the Sensory Integration and Praxis Test, (Ayers, 1982; 1989) and therefore interpretation of behaviour has been based primarily on the children's performance on these tests.

Conclusion

Even though literature has suggested that children with tactile defensiveness may limit the amount of and variety of objects and textures explored/ manipulated (Sears, 1981), there has been no objective, systematic exploration of this finding, i.e. to determine what types of objects or textures result in a defensive response / withdrawal and whether these objects or textures are consistent across individuals, and whether they change or remain constant over development. In addition, the questionnaires that have been used to obtain information on tactile defensive behaviours and on the sensory history of individuals have only gathered general information about what materials elicit defensive reactions and general information about the child's behaviour patterns. For example, a typical question on tactile sensitivity is, 'Is your child sensitive to certain fabrics?' and another is, 'Does your child react emotionally or aggressively to touch?' Therefore, no specific information is gathered on the type of tactile stimulation or material that causes such responses, and whether that stimuli change across development. A broader theoretical question that remains is what effect such a deficit would have on the child's interaction with the environment, namely their object exploration and manipulation, and consequently their cognitive and social development. Highlighting the impact of sensory issues, Ashburner, Ziviani and Rodger (2008) explored the relationship between sensory processing, behaviour and later educational outcomes and found that sensory under-responsiveness, sensory seeking, and auditory filtering difficulties was related to academic underachievement in the children with autism. However, this research did not specifically focus on tactile sensitivities and later developmental function.

1.6 Thesis structure

This thesis specifically aims to explore tactile sensitivity. The main questions that rise from the theoretical explanations of tactile defensiveness are: 1) is the unusual tactile response to tactile stimulation due to extreme texture preferences and aversions, 2) due to an inability to accurately discriminate tactile stimuli which results in either a fascination with, or aversion to certain tactile stimuli, or 3) due to an inability to accurately integrate tactile information in order to create a unitary tactile experience.

The research provided in this thesis systematically investigates possible differences in texture preference, fine texture discrimination, and cross-modal matching of texture between individuals with Autism Spectrum Disorders (ASD), Attention Deficit/ Hyperactivity Disorder (ADD/ADHD), and typically developing individuals. The proposed research aims to provide a more comprehensive investigation of unusual tactile response through exploring tactile sensitivity in typical and atypical development, and by doing so contribute to the understanding of the causes of unusual tactile response observed in autism specifically. The first line of enquiry (chapter 2) explores preferences and aversions to everyday textures to determine whether there are certain textures that are more aversive to individuals with ASD than to typically developing individuals. Two studies aim to determine whether texture preferences are similar between typical and atypical groups, and whether texture preference is related to a specific texture dimension (e.g. hard-soft), or texture complexity. Based on anecdotal reports, it is expected that texture preferences and aversions will be different between typical and atypical groups.

The second line of enquiry (chapter 3) considers whether reported differences in texture preference and tactile response may be due to perceptual differences in tactile sensitivity between typical and atypical samples. Explanations of tactile defensiveness suggest possible heightened sensitivity (e.g. Case-Smith, 1991) and / or differences in tactile discriminative ability (Royeen & Lane, 1991). The study will explore possible differences in a fine texture discrimination task, with the prediction that individuals with autism may have heightened sensitivity to tactile stimulation and thus would be more accurate in discrimination of fine texture. A heightened sensitivity to certain texture may account for the unusual fascination with or aversion to certain textures.

The third line of enquiry (chapter 4) considers whether discrepancies in tactile response between typical and atypical development may be explained by a difficulty matching visual and tactile information. In a series of cross-modal studies, visual-tactual matching of texture in typical and atypical development was explored. Previous studies have found contradictory results, with some studies showing better cross-modal performance in autism (eg. Nakano, Kato and Kitazawa, 2011) and other research finding poorer cross modal performance in autism compared to typically developing individuals (e.g. Oberman & Ramachandran, 2008). It was proposed that perhaps a mismatch of expectation of what is felt and what is seen, may account for unusual tactile response. A further study explores visual-tactual texture matching within a meaningful context. In this study, a visual texture scene was created to determine whether a less artificial texture matching task would aid cross-modal matching in the ASD group. Together these lines of enquiry will further our understanding of unusual tactile processing in typical and atypical development and may give us insight into why some individuals with autism and some individuals with ADHD respond differently to tactile information.

Chapter two

Texture Preference and the Development of the Texture Preference and Aversion Questionnaire (TPAQ)

2.1. Introduction

Chapter one emphasised the role of touch in development and highlighted the importance of exploring tactile sensitivity in typical and atypical development. The chapter considered the adverse effects of tactile defensiveness, particularly for the child's active exploration of their environment and considered the possible effects for later social and cognitive development. To begin to understand the unusual tactile response observed in individuals with autism, a texture preference and aversion scale was developed in Study 1. Based on anecdotal reports it was predicted that there would be significant differences in texture preference between typically developing individuals and those diagnosed with autism and ADHD. Study 2 explores whether texture complexity is a determinant of preference. Literature suggests that stimulus complexity can result in heightened arousal, particularly for individuals with autism. The prediction is that individuals with autism would prefer less complex stimuli.

2.2 Texture sensitivity and preference

There has been very little psychological research conducted on texture preference. Research has focussed on oral texture preference in food manufacturing (Hough & Sanchez, 1998) and texture preference in the clothing industry (Li & Wong, 2006). Developmental research has rarely explicitly explored texture preference, but a few cross-modal transfer studies have hinted at texture preference in infancy (e.g. Bushnell & Weinberger, 1987; Sann & Streri, 2007).
Tactile sensitivity in infancy has been studied more often with respect to interpersonal relations and body-to-body contact with the mother than in relation to contact with the external physical world (e.g. Campbell & Taylor, 1980). Most studies of infants' haptic abilities have focussed on the object property of shape, whereas very little research has been conducted on infants' haptic sensitivity to texture (Bushnell & Boudreau, 1991). Using the violation–of–expectancy paradigm, Bushnell (1982) found that both 9.5-month-olds and 11-month-olds detected a visual-tactual discrepancy between a fur-covered cylinder and a knobbly cylinder made of smooth plastic.

Similarly, Bushnell and Weinberger (1987) found that under certain conditions, 11-month-olds detected a discrepancy between a fur-covered cube and a smooth wooden cube. In a third study, Bushnell, Weinberger and Sasseville (1989) presented infants with wooden dowels to grip. On the back of the dowels, out of vision for the infants, there was a strip of fur, sandpaper, bumps, or it was plain. Results revealed that 12-month-old infants, and to a lesser degree 9-month-olds, were more likely to lean over to see the back of the dowel after gripping a textured dowel than after a plain one. These studies explored infants' ability to make crude texture discriminations and were not examining texture preference per se. However, all studies indicated an ability to differentiate between textures and a preference for novelty. Furthermore, Bushnell and Boudreau (1991) found that when 8-10 month-old infants were given cylinders covered in different textures (i.e. smooth, furry, rough or compressible), infants moved their fingers over the objects for longer durations when they were rough or furry that when they were smooth. In support of these findings, Sireteanu, Encke, and Bachert, (2005) investigated infants' texture segmentation and preference using a visual search paradigm and found that infants between 1 and 12 months old typically prefer more salient targets.

Morange-Majoux, Cougnot, and Bloch (1997), investigated tactual exploration of textures in infants 4-6 months. They were particularly interested in the infants' hand activity on the surface of an object whose tactual texture was heterogeneous, but that were not discernible visually. Infants explored a horizontal cylinder whose surface had irregular, smooth and rough parts (a wooden cylinder painted with 'tachist' pattern). Results showed that cumulative contact time did not increase with age, but was characterised by increasing action. No overall texture preference was observed.

However, it is not clear whether these infant studies indicate a preference for texture per se, stimulus discrimination or simply a preference for novel stimuli. Research has evidenced that typically developing infants are known to seek out novelty (Berlyne, 1958; Hershenson, 1964), and seem to have an innate visual preference for novel stimuli (Franz, 1964; Wetherford & Cohen, 1973). It is not apparent that these studies have controlled for stimulus novelty. In addition, the studies have used a limited variety of textures and rudimentary experimental design. Curry and Exner (1988) examined tactual preference in children with and without cerebral palsy of a variety of textures including fur, foam, plastic brush bristles, sandpaper and yarn. Results indicated a preference for hard objects in children with cerebral palsy, but again no significant preference was observed in typically developing children.

An earlier study by Klein (1963) exploring tactual preference in young children found that preference changes from texture to shape with age, i.e. by 8 years old children will match objects by shape, whereas earlier matching is determined by texture. Gliner (1967) examined tactual discrimination thresholds of shape and texture in young children. By presenting pairs of shapes and texture patches in a same/different task to two groups of children (5-year-olds and 8-year-olds), results revealed an increase in texture sensitivity with age, but not to shape. Both Klein and Gliner's results indicate an early predominance with texture over shape in matching tasks. Hanninen (1976) examined whether age, gender and handedness predicted texture preference in blind and sighted participants aged between 10-19 years old. They also examined whether texture preference affected accuracy of tactual discrimination of the length of strips of material. Preference appears to be related to soft/smooth texture dimension, as most preferred textures for both blind and sighted individuals were felt and fur, and least preferred were the abrasive grit papers. Texture preference was also found to influence accuracy of tactual discrimination in both groups. Most accurate discrimination of length was found with the least preferred textures, i.e. grit papers, and least accurate with most preferred textures for both groups.

Ekman, Hosman, and Lindstrom (1965) examined roughness perception and preference in adults. Materials included 5 pieces of sandpaper, 1 piece of cardboard and 1 piece of ordinary writing paper. Participants were presented with pairs of surfaces and asked to give an estimation for roughness, smoothness and preference (in terms of pleasantness). Results showed that for nearly all the participants, preference was directly proportional to smoothness. By comparison to research on texture preference in adults, preference in infancy appears to be related to novelty, whereas texture preference in adults is directly related to smoothness. What appears to be an innate preference for novelty in infancy drives exploration and active engagement with the environment, which is essential for development (Piaget, 1954), as discussed in Chapter 1. In contrast, individuals with ASD commonly avoid novelty, and have a need for sameness (e.g. Maes et. al. 2010). As previously discussed, individuals with ASD can be *sensory avoidant*, or *sensory seeking* i.e. deliberately avoiding certain stimulation or seeking out sensory stimulation (Ayres, 1972; Tomchek & Dunn, 2007; Ben-Sasson et al., 2008). The question is what contributes to this unusual tactile behaviour. Does the texture of an object or surface trigger avoidant or seeking behaviour?

2.3 Texture dimensions and preference

Studies that have used everyday textures have provided information on texture dimensions. Yoshida (1968) investigated haptic perception of object surfaces (e.g. paper, glass, bamboo and stone) and various fabrics (e.g. silk, wool and cotton). Participants had to rate the similarity of 25 samples on a 5-point scale. It was concluded that stimuli were characterised according to two groups; hard, heavy, cold & rough, and soft, light, warm & smooth. Picard, Dacremont, Valentin and Giboreau (2003) further explored perceptual dimensions of everyday tactile textures (car seat materials). Participants were asked to sort 24 seat materials with different tactile properties on the basis of perceived similarity. Multidimensional scaling analysis indicated no more than four dimensions for tactile texture, i.e. soft / harsh, thin / thick, relief, and hardness. In addition, Hollins et al. (1993) investigated tactile texture space in terms of its perceptual dimensions using everyday surface textures, such as wood, sandpaper, velvet, corduroy and synthetic fur. Participants were asked to sort materials based on perceived tactile similarities. Multidimensional scaling analysis revealed three dimensions: smooth-rough scale, hard-soft scale, and flat-bumpy (which was similar to smooth-rough). The additional warm-cold and sticky-slippery scales were not found to be independent dimensions, but the rough and hardness scales were independent. Further studies by Hollins and Risner (2000) concluded that two main texture dimensions (rough-smooth and hard-soft) might account for tactile perception. This finding supports Yoshida's (1968) previous texture groups that fall into these dimensions; hard-soft and rough-smooth.

2.4 Complexity preference

Research has found that texture preference is related to smoothness, but there is no research that has considered texture complexity as a variable that could affect tactile texture preference. That is, perhaps it is rather the level of *texture complexity* that may affect preference, and not the type of texture, e.g. fur or grass. In the literature there are some differences in what constitutes stimulus complexity (e.g. Fiske and Maddi, 1961), but for the purposes of this research stimulus complexity has been defined as "*the amount of variety or diversity in a stimulus pattern*, *with the*

degree of complexity positively related to the number of distinguishable elements and to the extent of dissimilarity between the elements' (Berlyne, 1958).
Not only is stimulus complexity an important determinant of visual attention in infants (Moffett, 1969), but they show an increase in visual preference for complexity (Frantz, 1958), and seek out increasingly complex stimuli (Berlyne,1960; Dember,1960). Stevenson and Lynn (1971) found a linear positive relationship between preference and complexity in children aged 3.5 years to 7 years old, with a stronger relationship with increased age.

It has also been found that adults rate complex stimuli (polygons and figures) as more 'interesting', and less irregular patterns as more 'pleasing' (Berlyne,1963; Eisenman,1966). However, Terwilliger (1963) found that pleasantness ratings decrease with increased pattern complexity and the strength of the relationship depends on individuals' complexity tolerance, referred to as their adaptation level. Dember and Earl (1957) suggest that individuals have a preferred level of complexity, with preference for complexity decreasing the further away from their desired level. The notion that individuals may have different levels of preference for complex stimuli is related to the proposal of a complexity-simplicity personality dimension with perceiving and dealing with complexity on one end of the scale and dealing with simplicity on the other. This trait has been applied to a number of aspects such as interpersonal relations, social conformity, adherence to tradition and sensual experience amongst others (Eisenman, 1966).

Complexity in atypical development

There is very limited research exploring preference for complexity in atypical development, some of which is outdated. For example, Spitz and Hoats (1961) explored differences in preference for pattern complexity in typically developing children and children with lower mental function (referred to as retardates in this literature). They found preference for low complexity stimuli in both groups, with individuals choosing the *less irregular* pattern more often than the *more irregular* pattern. This is consistent with a study by Berlyne and Lawrence (1963) finding that individuals gave higher rankings to *less irregular* patterns than to *more irregular* patterns.

More recently, Bertone, Mottron, Jelenic and Faubert (2005) explored the effect of stimulus complexity on visual identification of orientation in autism. In an orientation identification (visuo-spatial) task participants were presented with first-order and second-order static stimuli.

The static stimuli consisted of gratings presented either horizontally or vertically. First-order stimuli were noise motion stimuli, defined by luminance. The luminance contrast was varied to determine the orientation threshold. Second-order stimuli were noise stimuli that varied in texture contrast. The results showed that orientation thresholds were significantly lower for individuals with autism than typically developing individuals for simple gratings (first-order stimuli) demonstrating superior performance in autism in tasks requiring attention to small elements. However, thresholds were significantly higher for complex static stimuli (second-order). Authors suggest that visuo-spatial performance in autism is stimulus complexity dependent.

2.4.1 *Anxiety, personality and complexity preference*

Individuals with autism tend to avoid the unknown and are inclined to have *intolerance of uncertainty*, which is a dispositional characteristic that results in negative beliefs about uncertainty and its consequences. Individuals who score high on intolerance of uncertainty have the tendency to react negatively (emotional, cognitive, and behavioural) to unfamiliar or to uncertain situations and events (Buhr & Dugas, 2009). Intolerance of uncertainty is associated with high anxiety in individuals with ASD (Boulter, Freeston, South & Rogers, 2014). Sensory under- and over-responsivity was also found to be significantly related to 'insistence of sameness', mediated by anxiety and intolerance of uncertainty (Wigham, Rogers, South, McConachie & Freeston, 2014). Literature on tactile defensiveness mentions heightened anxiety levels in individuals with tactile defensiveness (Kinnealey & Fuiek, 1999; Green & Ben-Sasson, 2010). High anxiety in individuals likely to have tactile defensiveness might be a reason for avoidance of exploration (i.e. to reduce / prevent anxiety).

Personality is another variable that interacts with complexity preference. Literature exploring *complexity-simplicity* refers to personality differences in stimuli preference. For example, it has been suggested that extraverts prefer more complex stimuli (Bartol & Martin, 1974). Christensen (1962) correlated texture preference to personality traits and found that a preference for complex unstructured texture is associated with responsiveness, tolerance of anxiety and a preference for creative activity in favor of routine. This contrasts with ASD individuals' need for structure and routine. Eisenman (1968) explored the notion that preference for complexity or simplicity corresponds to complexity / simplicity cognitive style. The results suggest that a preference for visually simpler shapes is associated with avoidance of threatening information and more defensive behavior, whereas individuals with a preference for complex shapes are more tolerant of threatening information and are more independent. This suggests that individuals who prefer complexity are more open to experience which deviates from expectation. A preference for simple structured textures was associated with social insecurity and, in males only, with worry, conflict and confusion. This is comparable to individuals with ASD and their need for sameness / intolerance of uncertainty, and thus their avoidance of anxiety provoking stimuli.

Complexity Theory (Dember & Earl, 1957) proposed a complicated relationship between stimulus complexity and arousal of the individual. According to the theory, individuals have a preferred level of complexity and their preference for other levels of complexity decreases with increased distance away from their preferred level, i.e. moving outside their complexity tolerance. In support, Christensen (1962) suggested that individuals differ in their sensitivity to be aroused, and in the ability to cope with arousal, and therefore may not avoid complexity if they are able to cope with that level of arousal. Berlyne (1960, 1963) explored this issue in detail, and suggests that stimulus complexity is related to the arousal of behaviour. Accordingly, affect is produced by stimuli that are of a certain complexity value. This value is determined by the individual's normal level of stimulation (arousal) and their adaptation level. It is proposed that this in turn effects exploratory behaviour. For example, Berlyne and Lewis (1963) found that heightened arousal increases exploration (on a button-pressing task) and increases choice of more complex (irregular) patterns. In comparison, individuals who are hyper-responsive to sensory stimulation (over-arousal) have been found to avoid exploring certain stimuli (Baranek et al. 2006; Dunn, 1997).

Conclusion

Texture preference has primarily been examined with typically developing adults. However, anecdotal reports refer to specific preferences and aversions of food and fabric in individuals with autism (Baranek, Foster & Berkson, 1997). The anecdotal reports of individuals with autism who experience aversive reactions to materials refer to everyday materials, such as cotton shirts and woollen jumpers, yet no empirical data exists exploring texture preferences and aversions in typical and atypical individuals. With reference to individuals with tactile defensiveness, even though literature has suggested that children with tactile defensiveness may limit the amount of and variety of objects and textures explored/ manipulated (Sears, 1981), there has been no objective, systematic exploration of this finding, i.e. to determine what types of textures result in aversive behaviour and whether these textures are consistent across individuals and whether they change or remain constant over development.

In addition, the questionnaires that have previously been used (eg. Sensory Experiences Questionnaire; Baranek, David, Poe, Stone & Watson, 2006; Sensory Profile; Dunn, 1999) to obtain information on tactile defensive behaviours and on the sensory history of individuals have only gathered general information about what materials elicit defensive reactions and general information about the child's behaviour patterns. For example, a typical question on tactile sensitivity taken from the Sensory Profile (SP) is, 'Is your child sensitive to certain fabrics?' and another is, 'Does your child react emotionally or aggressively to touch?' Therefore, no specific information is gathered on the type of tactile stimulation or material that causes such responses, and whether these particular items change with development. That is, current measures of tactile defensiveness are vague about the specific textures that individuals find aversive or are fascinated by. For example, one item may ask how likely a child is "to avoid certain textures" without specifying a particular texture. And other measures may indicate whether a child is hypo-responsive or hyper-responsive to certain textures without specifying a texture. As noted above there has been little information gathered on texture preferences in typical and atypical development, and no such information, to my knowledge, has been attained for individuals who exhibit tactile defensive behaviours.

As noted previously, little is known about tactile sensitivity and preference. A baseline of tactile preferences and aversions across development is needed for comparison, to determine whether preferences and aversions are consistent across development, and whether individuals deemed to have sensory abnormalities have similar preferences and aversions to typically developing individuals. Is the aversion or excessive preference to certain textures in individuals with tactile defensiveness an extreme of the same pattern of preferences or is it a qualitatively different pattern? The overall aim of the first study is to explore tactile texture preferences and aversions across typical and atypical development through the use of a questionnaire. For the purposes of this study, The Tactile Preferences and Aversion Questionnaire (TPAQ) has been designed based on available questionnaires that are presently used to identify tactile defensiveness (Dunn, 1994; Bauer, 1977) in respect to what textures needed to be included, and on symptoms that have been reported in previous literature (e.g. Ayers, 1964; Larsen, 1982; Leekam, Nieto, Libby, Wing & Gould, 2007). Consequently, previous research gives little detail of the types of tactile stimuli that elicit aversive responses. Therefore, the TPAQ was used to gather more specific information on the tactile preferences of children exhibiting sensory abnormalities. Exploring texture aversion in individuals likely to experience sensory processing abnormalities it made sense to include those textures that individuals come into contact with daily, such as cotton, wool, grass and leather. The Sensory Profile (SP; Dunn, 1999) was used to examine differences in sensory processing patterns between typically developing individuals and those with developmental disorders. It is not known whether individuals with tactile defensiveness have different patterns of texture preference and aversion as typically developing individuals, or whether perhaps their *sensory experience* of them is more intense.

2.5 Study 1: Tactile Preferences and Aversions

Study 1 explores texture preference in typical and atypical development. A questionnaire, the TPAQ, was constructed based on items from standardised sensory questionnaires (such as the Sensory Profile; Dunn, 1999), the DISCO data (Leekam et al., 2002) and in discussion with teachers and parents of individuals recognised to have sensory difficulties. The textures listed in the TPAQ were identified from available and current questionnaires, anecdotal reports and data obtained for the DISCO autism diagnostic tool. The DISCO data had a free comment box where parents were able to list any materials or foods that their child was particularly averse to or fascinated by. These were included in the TPAQ, (refer to Appendix A for the full questionnaire). The specific aims of this study are 1) to determine whether typically developing individuals have similar preferences and aversions to individuals deemed to have sensory abnormalities, specifically autism and ADHD, 2) to determine whether there are age effects for preference, and 3) to explore whether preferences and aversions fall on specific texture dimensions, i.e. hardness – softness, and roughness- smoothness.

Method

Participants:

Individuals were recruited from schools and nurseries across the North East of England. The Tactile Preference and Aversion Questionnaire (TPAQ) was distributed to 7 nurseries, 7 primary schools, 4 schools for individuals with autism and 1 school for individuals with ADHD. The questionnaire was completed by parents of children. Typically developing adults (+18 years old) completed a self-report adult version of the questionnaire. The demographic information of all those individuals who participated is represented in Table1 below (includes data from online pilot version). Ethics for this study was obtained from Sunderland University Ethics Committee.

Table 2.1: *Parent reported sample demographics for each ability and age group.*

	Age Group					
	0-23 months	2-5 years	6-12 years	13-17 years	18+ years	Total N
Typical	46	95	110	12	42	305
Autistic	0	18	37	12	14	81
ADHD	0	0	14	5	3	31
*Other	0	2	19	2	5	28

****Other*** *includes individuals with co-morbid disorders, and / additional sensory difficulties (including dyspraxia).*

Note: Where possible age groups have been mapped onto educationally significant stages, however because of sample recruitment sometimes these boundaries have been changed to ensure more equal group sizes.

Materials and Procedure:

Description of TPAQ-

Designed for the purposes of this study, the Tactile Preference and Aversion Questionnaire (TPAQ) aimed to identify texture preferences and aversions across typical and atypical development. In addition, it was used to create a baseline of preferences and aversions across typical development. The TPAQ is a caregiver questionnaire which consists of 31 items (textures) on a rating scale from ‘like very much’ to ‘dislike very much’ (1 – 5). The TPAQ states “*Please indicate on the scale below to what extent your child likes to feel the following materials. Indicate by circling, (1= Like very much, 3 = Neutral to the feel of that material, and 5 = Dislike very much)*”, and then lists texture items, such as Wool, Silk, Fur, Wood etc.

The TPAQ was taken to schools and nurseries across the North East of England where teachers distributed them. Questionnaire packs contained return envelopes that were collected from the school or posted back to the experimenter.

Piloting the TPAQ:

The TPAQ was piloted with an online version. The response rate was good (N=88). The Cronbach's alpha coefficient for internal consistency of the 31 items (scale questions) was .906, indicating that the scale had good reliability.

Sensory Profile:

The Sensory Profile (SP; Dunn, 1999) is a 125-item parent report questionnaire which gives a measure of a child's response to everyday sensory events / experiences for children aged 2-12 years old. Items are divided into separate subscales, examining different sensory modalities (e.g. auditory filtering, visual processing, vestibular processing, touch processing, multisensory processing, oral sensory processing) and the regulation of emotional and social responses. The SP allows for sensory processing information to be examined on four quadrants; Low registration, Sensation Seeking, Sensory Sensitivity and Sensation Avoiding, defined below (Dunn, 2007):

Q1 Low Registration (or hypo-sensitivity): high sensory threshold and passive self-regulation strategy used. Individuals who score high on this quadrant tend to not respond to (or disregard) sensory stimuli. They exhibit a lack of responsiveness and appear not to detect incoming sensory information. Their behaviour may appear apathetic or lethargic and with lack of inner drive to initiate exploration.

Q2 Sensation Seeking: high sensory threshold and active self-regulation strategy. Individuals who score high on sensation seeking engage in actions that add more intense sensations to their bodies. They have a tendency to be inattentive and unfocused during tasks requiring learning and during social interactions.

Q3 Sensation Sensitivity: low sensory threshold and a passive self-regulation strategy. Individuals who score high on sensation sensitivity tend to respond more quickly to sensation, respond with more intensity or for a longer duration than those individuals with typical sensory responsiveness. Behaviour exhibited may range from active, impulsive, negative or aggressive, to withdrawal or avoidance of sensation.

Q4 Sensation Avoiding: low sensory threshold and active self-regulation strategy. The behaviour of individuals who score high on sensory avoiding is characterized by rigidity and difficulty in accommodation and transition. They often feel threatened by sensation, thus tend to exhibit avoidant behaviour.

For the purposes of this study the SP was used to gather sensory processing information to explore differences in sensory processing patterns between typically developing individuals and those diagnosed with autism.

Data analysis:

Data was only used from the typically developing (TD), ASD and ADHD groups. A mean preference rating was calculated for each individual for each texture dimension (smooth, soft, hard and rough). There were seven texture items in the Smooth, Soft and Hard dimension, and five items in the Rough dimension. The texture dimensions used were based on those defined by multidimensional scaling studies (e.g. Picard et. al., 2003). Only descriptive statistics and t-tests are presented for the 'sticky-slippery' dimension as it is not a recognised texture dimension. Mixed model analysis of variance (ANOVA) was used to explore preference difference across participant groups and age differences in the typical and ASD sample. Note that the 0-23 month-old group was not included when comparing group differences between ASD and TD, and the 0-23 month-old & 2-5 year-old group was not included in the TD and ADHD group comparison. Age differences could not be examined in the ADHD sample due to small sample size.

Data was checked for normality and none of the texture dimensions were bimodal with a similar spread of responses across groups, i.e. most textures were rated as neutral or a preference. In order to explore interactions, ANOVA was used. Post-hoc independent t-tests were used to explore significant main effects and interaction. Alpha level of $p<.05$ was used for all analyses.

Results

Descriptive statistics for separate textures across entire sample

The mean liking score for each item was calculated for each participant group and summarised graphically. Only items that fit into specific texture dimensions or that show clear differences are included below. Items rated as 1 are most preferred and items rated as 5 are least preferred and are considered an aversion. A low mean score represents preference and high mean score represents aversion.

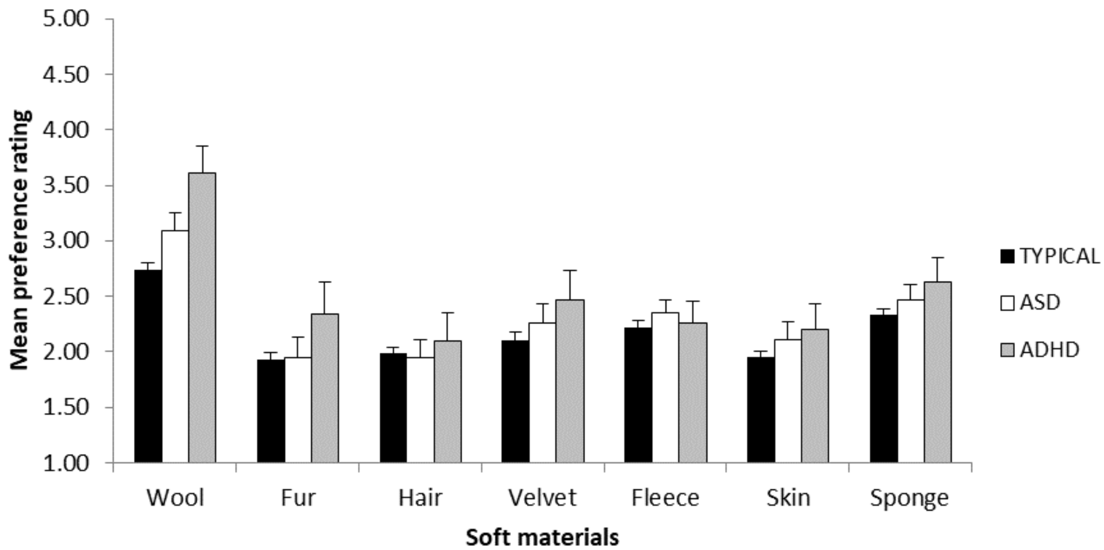


Figure 2.1: *Representation of texture preference for soft material across participant groups. Error bars represent standard error.*

Figure 2.1 shows that texture preference for soft materials appears to be similar across the three participant groups. Mean preference score is low across items (textures) indicating a preference for soft texture, except for Wool in the ADHD group.

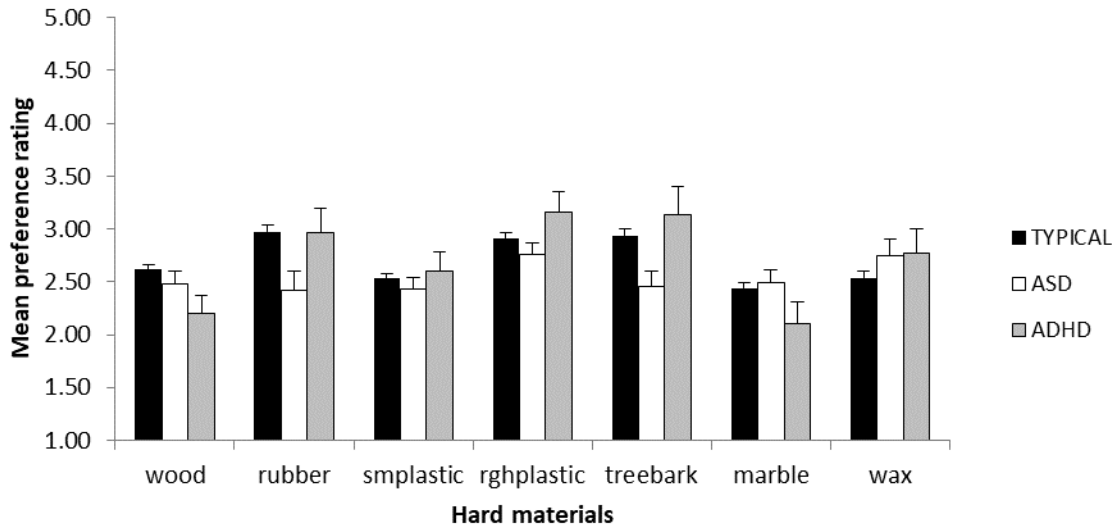


Figure 2.2: *Representation of texture preference for hard materials across participant groups. Error bars represent standard error.*

The items in Figure 2.2 are rated as a preference or as neutral. Individuals with autism appear to rate hard materials more as a preference compared to typically developing individuals and individuals with ADHD.

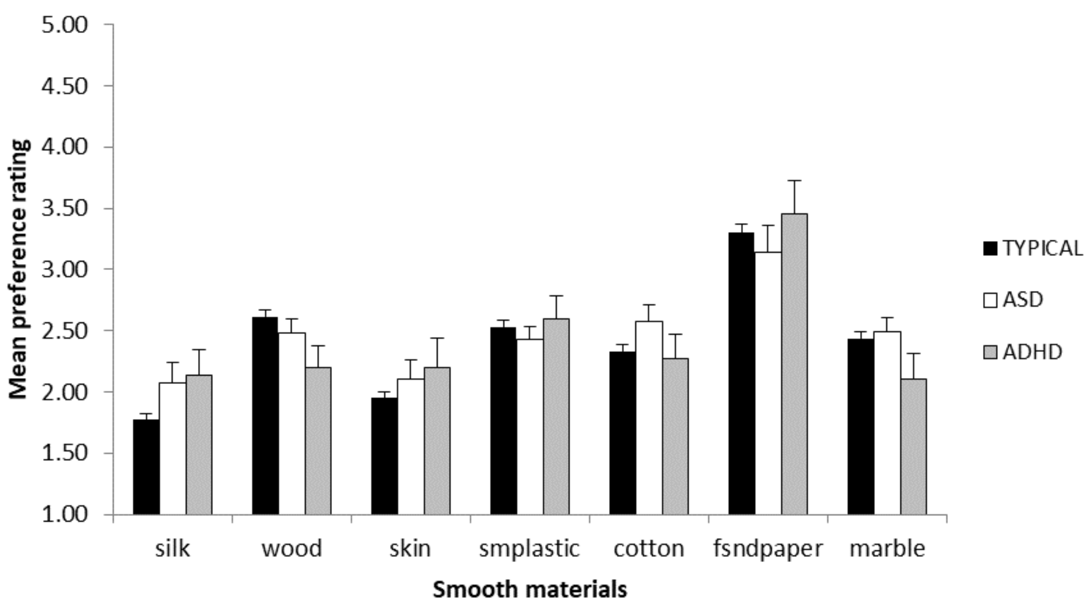


Figure 2.3: *Representation of texture preference for smooth materials across participant groups. Error bars represent standard error.*

Preference ratings of items in Figure 2.3 are all low expect for fine sandpaper, indicating that preference appears to be related to smoothness in all participant groups.

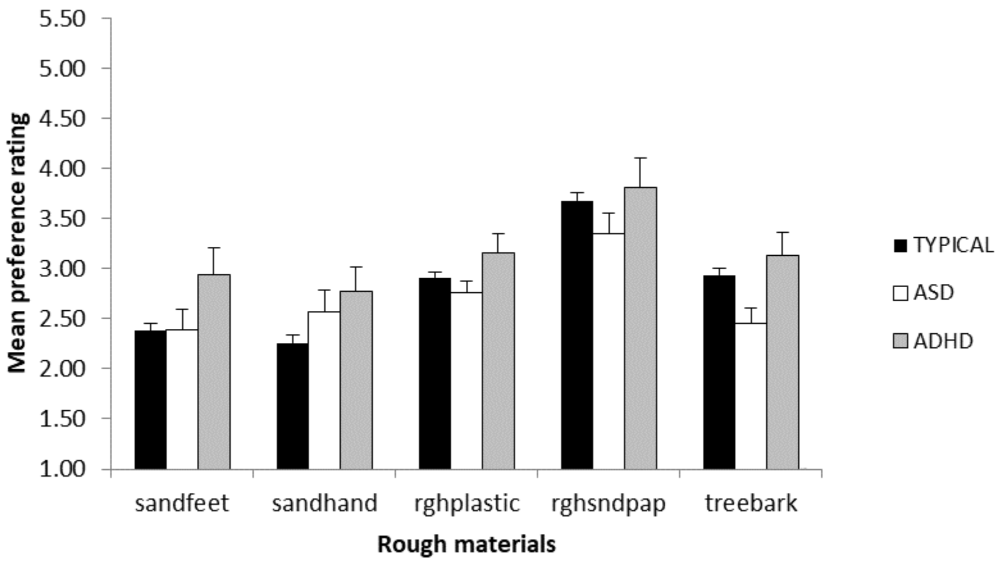


Figure 2.4: *Representation of texture preference for rough materials across participant groups. Error bars represent standard error.*

The ratings for items in Figure 2.4 are highest for rough sandpaper. This illustrates that this item which was rated as aversion falls on the rough texture dimension.

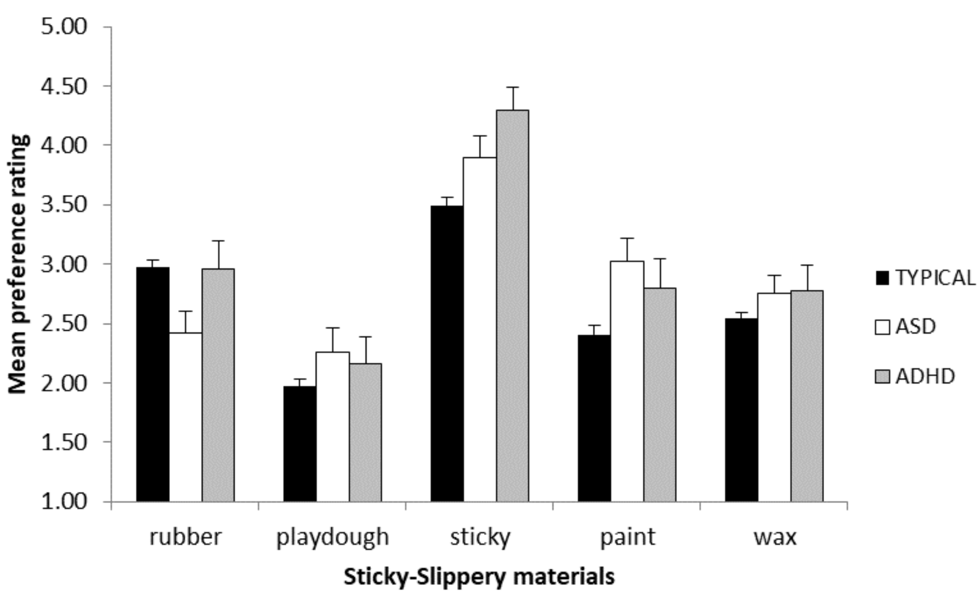


Figure 2.5: *Representation of extreme aversive rating to 'sticky-slippery' textures. Error bars represent standard error.*

Figure 2.5 above illustrates an extreme aversion to item 'sticky', which does not fall into a recognised texture dimension. An average score was calculated for 'sticky-slippery' items for each participant group. Individuals with ASD had a higher mean preference score ($M = 2.91$) than the typical sample ($M = 2.64$). An independent t-test was conducted and was found to be significant, ($t(353) = -2.174$, $p < .05$). Individuals with ASD were found to be more aversive to 'sticky-slippery' texture than typically developing individuals. Individuals with ADHD had a higher mean preference score ($M = 2.98$) than the typical sample ($M = 2.64$, $t(336) = -2.24$, $p < .05$).

Group differences in Preference:

Typical and Autistic (TYP N=259. ASD N=81) -

A 2 X 4 mixed model analysis of variance (ANOVA) was conducted to explore differences in texture preference across participant groups. A significant main effect of texture dimension preference was found, ($F(1,1044) = 26.38$, $p < .001$). Preference ratings of the four texture dimensions (Soft, Hard, Rough and Smooth) were significant except no difference was found in preference rating between 'hard' and 'rough' ($p = .279$). For both groups, the most preferred texture dimension was 'soft' (typical group, M = 2.18; and autistic group M = 2.28), and least preferred texture dimension was 'rough' (typical, M = 2.68; and autistic group M = 2.61). No significant main effect of group was found ($F(1,248) = .003$, $p = .953$). The overall preference of texture dimensions is similar for the typical and autistic group. There was no significant interaction between texture dimension and group, ($F(3,1044) = 2.07$, $p = .103$).

Typical and ADHD (TYP N=164, ADHD N=31) -

A 2 X 4 mixed model analysis of variance (ANOVA) was conducted to explore differences in texture preference across participant groups. A significant main effect of texture dimension preference was found, ($F(3,996) = 33.50$, $p < .001$). Pairwise comparisons for preference ratings of the four texture dimensions were all significant except no difference was found in preference rating between 'soft' and 'smooth'. A significant main effect of group was found, (F(1,332) =

4.22, $p < .05$). Overall mean preference score was higher in the ADHD group across all texture dimensions, indicating that these individuals rated textures as more aversive compared to typically developing individuals. A significant interaction between texture dimension and group was found ($F(3,996) = 5.30$, $p < .01$). The results are presented in Figure 2.6 below. Means did not differ significantly for the 'hard' texture dimension ($t(333) = .293$, two-tailed, $p = .769$) and 'smooth' texture dimension ($t(336) = .206$, two-tailed, $p = .837$). The ADHD group mean (M = 2.50, SD = .72) for 'soft' texture dimension was significantly higher ($t(336) = 2.81$, $p < .01$) than the typically developing group (M = 2.18, SD = .595), and the ADHD group mean (M = 3.12, SD = .92) for 'rough' texture dimension was significantly higher ($t(335) = 2.56$, $p < .05$) than the typically developing group mean (M = 2.69, SD = .89).

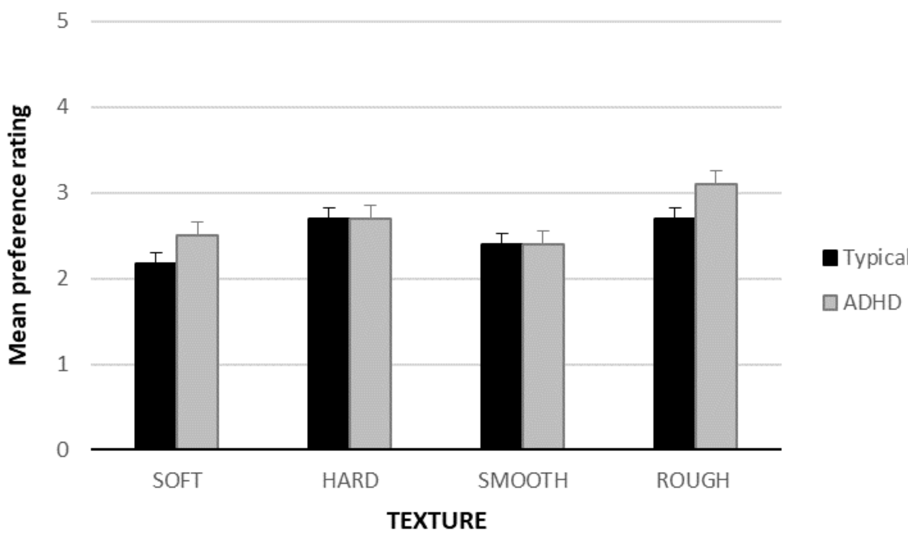


Figure 2.6*: Group difference in preference rating of four texture dimensions Error bars represent standard error*.

Age differences:

Typical developing sample (N=305) -

A 5 X 4 mixed model ANOVA was conducted to explore differences in texture preference across age group. A significant main effect of texture dimension preference was found, ($F_{3,876} = 22.63$, $p<.001$). Pairwise comparisons for preference ratings of the four texture dimensions were significant, except no difference was found in preference rating between 'soft' & 'smooth', and 'hard' & 'rough'. A significant main effect of age group was found, ($F_{1,292} = 14.19$, $p <.001$). Pairwise comparisons found that younger groups, 0-2 and 3-5 years, had significantly lower mean preference scores compared to older groups, 13-17 and 18+ years (*p* <.001). No significant age difference was found between younger groups, 0-2 and 3-5 years (*p* = .918), nor 3-5 and 6-12 years (*p* = .190). Younger groups rated textures more as a preference than an aversion. A significant interaction between texture preference and age was found, ($F_{12,876}$ = 4.39, p <.001). The results are presented in Figure 2.7 below. A similar pattern of preference is seen across all age groups, with less extreme variation in the smooth texture.

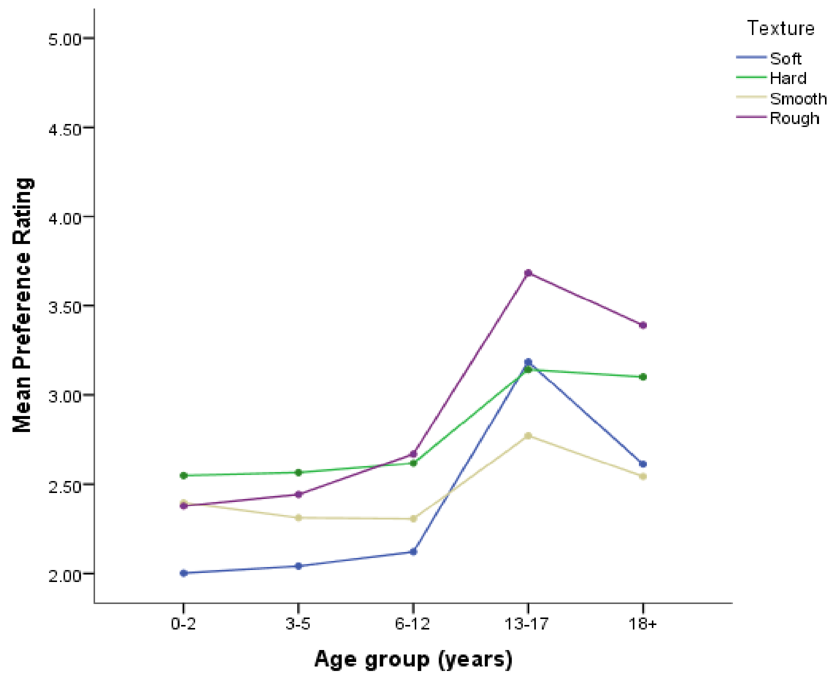


Figure 2.7: *Age differences in texture preference in typical sample.*

Autistic sample (N=81)

A 4 X 4 mixed model ANOVA was conducted to explore age difference in the autistic sample. No significant differences were found (p >.05 for all texture dimensions). As sphericity could not be assumed Greenhouse-Geisser was reported. [1]No significant main effects or interaction was found. The pattern of results is presented in Figure 8 below. It was concluded that texture preference is consistent across age in individuals with autism.

[1] The lack of sphericity accounts for the non-significant findings.

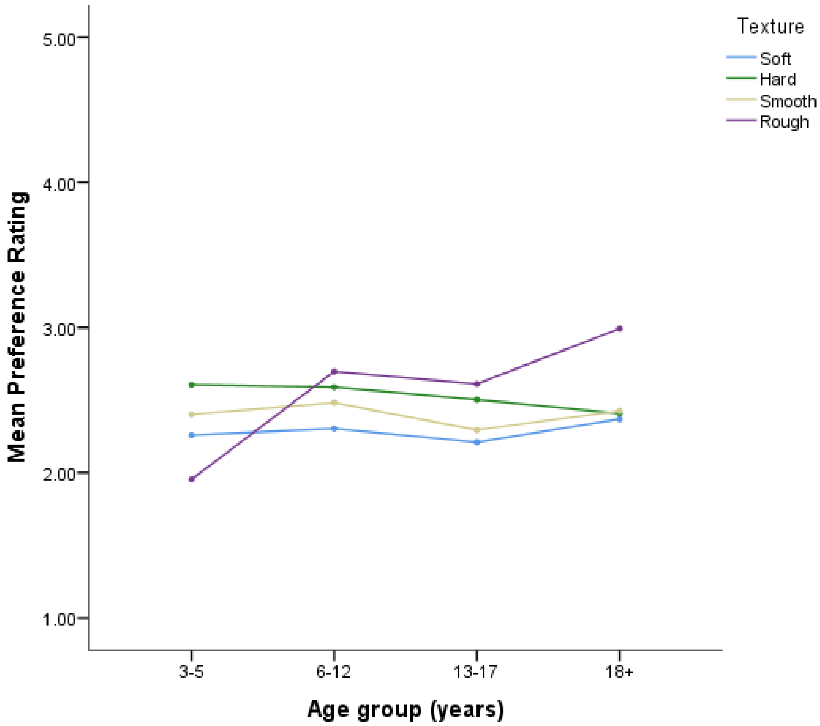


Figure 2.8*: Age differences in texture preference in Autistic sample.*

Sensory Profile Quadrant summary

Sensory Profile data was summarised according to the four behavioural quadrants; Low Registration (Q1), Sensation Seeking (Q2), Sensory Sensitivity (Q3) and Sensation Avoiding (Q4). The pattern of scores across these four quadrants give us an indication of whether typical and atypical individuals differ in their sensory processing profile. For each quadrant, scores indicate whether an individuals' sensory response is deemed as hyper-responsive (more than others), hypo-responsive (less than others), or the response is 'within the typically developing range'. For ease of comparison across participant groups the percentage of individuals scoring *more than others* (high), *less than others* (low) and *within the typically developing range* (TYP) was calculated for each quadrant. A summary for the ASD and typical sample is presented below.

Note: only have 5 completed SP for the ADHD, therefore not included in the SP summary.

ASD sample summary

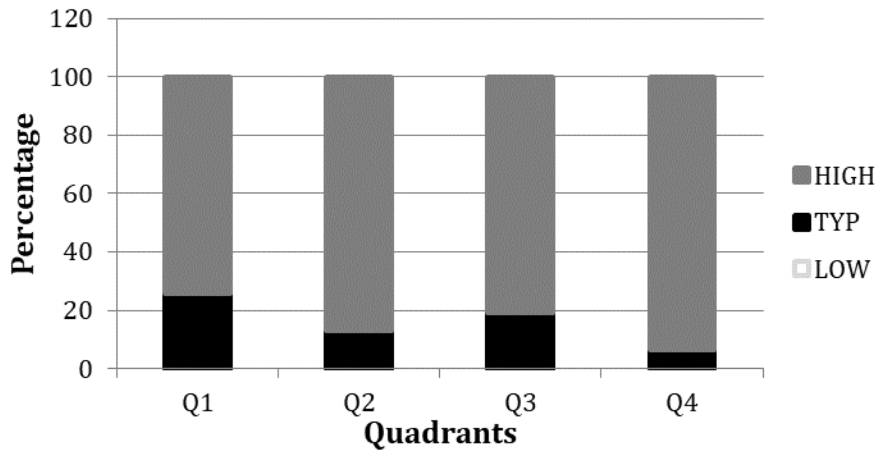


Figure 2.9: *Percentage of ASD sensory profiles across the four Quadrants for each range (N = 32).*

Figure 2.9 clearly shows that most individuals with ASD score in the *'more than other'* (high) category for each quadrant. Twenty of the 32 ASD individuals had scored in the "more than other / much more than other" range across two or more quadrants indicating **hyper-responsivity** to sensory input.

Typical sample summary

Sensory Profile data was summarised according to the four behavioural quadrants for the typical sample overall. When data was checked separately for the two age groups; 2 – 5 years and 6 – 10 years, the same pattern of sensory processing was found. The data is presented in Figure 2.10.

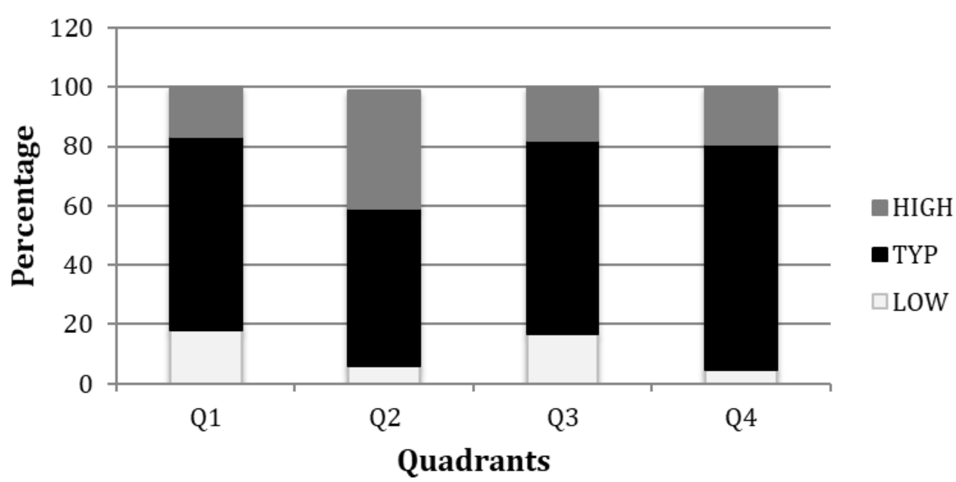


Figure 2.10*: Percentage of Typical sensory profiles across the four Quadrants (N = 66).*

Figures 2.10 above shows the sensory processing patterns for typical development, with most individuals scoring within the ‘typical range’ for each quadrant. Compared to the ASD group, 80% typically developing individuals scored within the ‘typical range’ on 2 or more quadrants.

ASD and typical comparison –

A 2 X 4 mixed model ANOVA was conducted to explore group differences in total scores the four quadrants. Significant group differences were found for each of the four quadrants; Low Registration (Q1) $F_{1,105} = 84.93$, $p <.001$), Sensation Seeking (Q2) $F_{1, 105} =52.42$, $p <.001$), Sensory Sensitivity (Q3), $F_{1,105} = 65.42$, $p <.001$, and Sensation Avoiding (Q4), $F_{1,105} = 136.47$, $p <.001$. Individuals with ASD have significantly different patterns of sensory processing than typically developing individuals.

[2] Sensory processing patterns were the same for the sensory quadrants when age groups (2-5 years and 6-10 years) were explored separately.

Conclusion

The aim of the TPAQ was to explore texture preference and aversion across typical and atypical development. It was predicted that individuals with autism would have different texture preferences or their preferences may be more intensely rated. Contrary to expectation, the results found that all groups preferred smooth textures. This is consistent with studies indicating preference is directly related to smoothness (e.g. Ekman, Hosman, and Lindstrom, 1965).

Another aim of the study was to determine whether texture preference remains consistent across age. In the younger typically developing group, textures were more likely to be rated as a preference than an aversion. By comparison, in the ASD group texture preference does not appear to change with age. The TPAQ also showed that texture ratings in the ADHD group were higher across all texture dimensions, indicating that texture was rated more aversive compared to typically developing individuals.

2.6 Introduction to Study 2 and development of materials

Study 2 aims to determine whether texture preference is related to stimulus complexity. The literature suggests that certain personality types have heightened anxiety and therefore would avoid complex stimuli. The research on personality differences in complexity preference has been conducted only with typically developing individuals, and there are no studies to my knowledge that have explored this research area in autism or ADHD. It is suggested that individuals likely to have tactile defensiveness would be more aversive to complex stimuli (i.e. show preference for simple texture). It is predicted that individuals with ASD would prefer less complex textures based on literature that proposes that individuals with ASD have difficulty processing complexity (visual modality, e.g. Bertone, Mottron, Jelenic & Faubert, 2005) and that individuals with ASD seek to reduce sensory stimulation to alleviate arousal (Hutt et al. 1964). In terms of individuals with ADHD, it was predicted that individuals with ADHD might either seek out additional stimulation (sensory seeking) and therefore prefer more complex texture or aim to reduce sensory stimulation due to low sensory thresholds (low complexity preference). It was predicted that typically developing individuals would prefer more complex texture give that there is support that from early infancy individuals seek out novelty in the environment and prefer more complex stimuli, which is contrary to the evidence of individuals with ASD who avoid exploration and aim to reduce over stimulation. Typically developing individuals who score high for extraversion will prefer more complex textures, and those who score low for anxiety would prefer more complex textures. It is unclear whether personality in individuals with ASD would affect preference, however, perhaps high anxiety (regardless of personality) in individuals with ASD would result in low preference for complexity.

2.6.1 *Development of materials*

Wallpaper sheets were used as complex textures which allowed the control of material type across different levels of surface complexity. In order to obtain a range in level of complexity, participants sorted the materials from least to most complex. Based on the participant rankings the top two, bottom two and middle two textures were used in Study 2.

Method

Stimuli development – *Sorting of texture complexity:*

Participants

Fourteen adult participants (8 males, 6 females, mean age = 19.5 years), all students at Newcastle University volunteered.

Materials

18 wallpaper sheets (10cm x 5cm) were used, which ranged in level of texture complexity. The sheets were painted white to control for texture differences in colour. The full set of materials (photographs of the wallpaper) can be found in the Appendix.

Procedure

Participants were asked to sort 18 textures (wall paper) from least to most complex. They were given an operational definition of complexity on which to sort the textures. The operational definition was, "*There are many ways that complexity can be defined, but for the purposes of this study a texture is simple when its elements have repetition and direction. A texture is complex when there is little repetition, or direction and there is a greater diversity in the elements*". Each texture was given a label from T1 to T18 for identification. Textures were randomly placed in front of the participant. The participants took approximately 10 minutes to sort the textures.

Results

The highest, middle and lowest ranked mean scores for level of complexity are presented in the table below.

Table 2.2: *Mean ranking scores for lowest, middle and highest ranked textures.*

Texture label	T1	T3	T10	T11	T16	T18
Mean Rank	1.32	2.98	9.72	11.44	15.87	17.39

Conclusion

From the sorting task, six textures were chosen, two in each level of complexity (high, medium and low). The two most and least complex textures were taken from the lowest and highest ranked items, and the two medium complex textures were taken from middle values (based on mean and median). Textures were labelled as H for high complexity (H1, H2), M for medium complexity (M1, M2) and L for low complexity (L1, L2).

2.6.2 *Study 2: Complexity Preference*

Method

Participants:

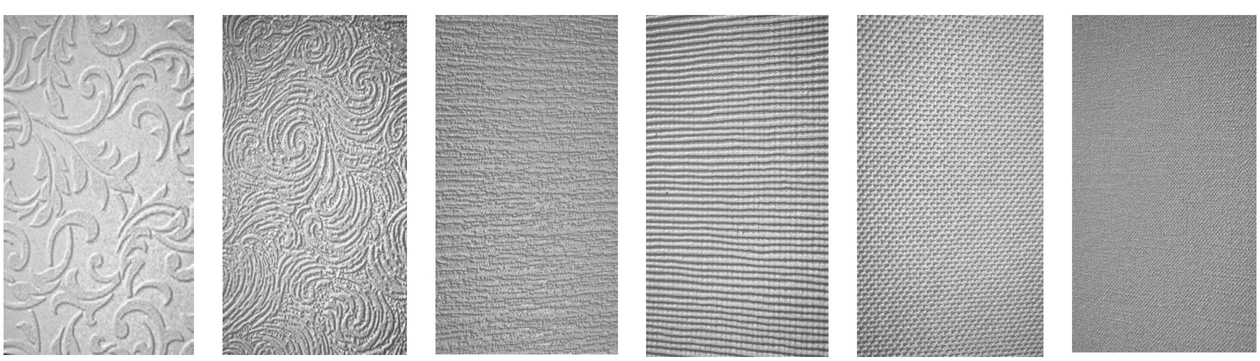
The sample consisted of 105 typically developing children (age range 5 -11 years, mean age = 8.24, std =1.19), and 24 individuals with ASD (aged range 7-14 years, mean age =10.59, std = 2.15). Four of these individuals were unable to complete the WISC, including two unable to complete task. The remaining 20 individuals with ASD had a complete data set including the WISC (measure described in detail below). Twelve individuals with ADHD (age range 8 -13 years, mean age = 11.67, std =1.44) took part, with one individual not completing the WISC. Data were analysed for 11 individuals with ADHD. Individuals with autism and individuals with ADHD have an official diagnosis.

Design:

A mixed design was used. The between-subjects factor was group, and the within-subjects variable was the modality used, with two levels, tactile and visual. The dependent variable was how often the participant chose the most complex texture.

Materials:

Six wallpaper sheets (10cm x 5cm), two from each level of complexity, were used in a visual preference task and a tactile preference task (refer to Figure 2.11). These sheets were then paired according to low or high *complexity contrast* (see description below).



H1 H2 M1 M2 L1 L2

Figure 2.11: *The six textures ranging from high to low complexity, indicating High (H), Medium (M) and Low(L) complexity.*

Comparisons of paired stimuli

High contrast comparison - In **high contrast** comparison, high complexity stimuli were paired with the low complexity stimuli. Comparison pairs were as follows:

H1 - L1	H1 - L2	H2 - L1	H2 - L2

Low contrast comparison - In **low contrast** comparison, high complexity stimuli were paired with medium complexity stimuli, and low complexity stimuli were paired with medium complexity stimuli. Comparison pairs were as follows:

H1 - M1	H1 - M2	H2 - M1	H2 - M2	M1 - L1	M1 - L2	M2 - L1	M2 - L2

Trials were presented randomly in a single block of 12 trials. Left – Right side presentation of the sheets was randomised across trials. For each trial, a score of 1 point was given for choosing the more ‘complex’ stimulus in the pair.

Procedure:

The 12 trials were presented once in each of the separate preference tasks; visual and tactile. Task order was counterbalanced across participants.

<u>Visual task</u>

Stimulus pairs were presented to the participant and asked, “Which one do you like?” (left/ right). Pairs were constructed according to level of contrast (as explained above). The participants were not allowed to touch the stimuli but could indicate preference by pointing to the chosen stimuli.

<u>Tactile task</u>

For the tactile task, identical stimuli were used as in the visual task. Stimulus pairs were presented inside a box with a window covered by a curtain to occlude vision. Participants were required to use their writing hand to haptically explore the textures and to indicate preference by pointing on the chosen texture.

Measures used:

WISC-IV short-form-

The Wechsler Intelligence Scales for Children, version IV (WISC-IV; Wechsler, 2003) is a standardised battery of tests designed to assess both verbal and performance IQ. For the purposes of this study, two tasks designed to produce a non-verbal IQ measure, and two tasks designed to produce a verbal IQ measure were administered.

Non-verbal tasks – The Block Design task consisted of a series of red and white patterns that need to be copied using a specified number of small red and white blocks. Each item increases in difficulty level, with a maximum score of 68. Picture Concepts task is comprised of 28 items. The participant is asked to choose two / three pictures (increasing with difficulty) that are semantically related (e.g. sail boat and vehicle). The maximum score is 28.

Verbal tasks - The Similarities task is comprised of 23 items. The participant is asked to state how two items are related (e.g. blue and red are both colours). The Vocabulary task consists of 36 items, in which participants are asked to define words which increase in difficulty (for example 'what is a bicycle'?). After five consecutive errors testing stops. A total verbal score was based on the sum of both tasks. For both tasks, some of the items can receive a score of 2 depending on detail given in the response. The total maximum scores are 44 and 68, for each task respectively. For matching purposes, the non-verbal and verbal total scores were summed to create a *WISC raw score*. Total maximum score is 208 (sum of the four tasks).

Personality measure-

The Inventory of Children's Individual Differences—Short Version (ICID-S; Deal, Halverson, Martin, Victor & Baker, 2007) was selected for use in this study. The ICID-S is a 50- item parent questionnaire, comprised of 15 subscales. From these 15 subscales, scores for Extraversion, Openness, Neuroticism, Agreeableness and Conscientiousness can be calculated. Internal reliability is above .75 for each sub-scale (Halverson et al. 2003). For the purposes of this study, only Extraversion and Neuroticism score was used.

Anxiety measure-

For the purpose of this study *The Spence Anxiety Scale (parent version; Spence, 1998)* was used to measure level of anxiety. The Spence Anxiety Scale consists of 38 items on a four-point rating scale from ‘never’ to ‘always’, including one open-ended question about other fears / phobias. The scale provides an *overall measure of anxiety* (a maximum score of 114). It consists of six sub-scales on different aspects of child anxiety; Panic attach and agoraphobia, Separation anxiety, Physical injury fears, Social phobia, Obsessive compulsive, and Generalised anxiety disorder / overanxious disorder. Internal reliability co-efficient of .93 (Spence, 1998).

Data analysis

All data was checked for normality to ensure distributions were not bimodal.

Results

Typical sample

The typical sample consisted of 105 individuals, 66 females and 39 males. The sample had a small age range, which has been divided into two age groups. The descriptive statistics are presented in Table 2.3 below. For visual and tactile complexity preference, the maximum score is 12. The score represents the number of complex stimuli chosen out of a total of 12 trials.

Table 2.3: *Descriptive statistics for the typical sample (mean with standard deviation in brackets).*

Age group	*N*	*CA*	*WISC raw score*	*Visual Preference*	*Tactile Preference*
6 -8 years	62	7.44 (.643)	72.10 (17.07)	8.23 (2.41)	7.18 (2.84)
9-11 years	43	9.42 (.626)	86.67 (19.34)	7.47 (2.82)	6.12 (3.34)

Gender differences

Independent t-tests revealed no significant gender difference in preference for visual complexity (t(103) = -1.54, p = .128), and tactile complexity (t(103) = -1.05, p = .298).

Age differences

No significant age difference was found in preference for visual complexity (t(103) = 1.48, p = .142) nor in preference for tactile complexity (t(103) = 1.75, p =.083)

Visual and tactile preference

A significant difference in preference for complexity was found between visual and tactile textures (t(104) = 3.68, p <.001), with highest preference for visual complexity (M = 7.91, std = 2.60) compared to tactile complexity (M = 6.74, std = 3.08).

Typical, ASD and ADHD sample comparison -

For group comparisons, typical, ASD and ADHD participants were matched on non-verbal ability (comprised of 2 WISC tasks) and overall WISC raw score (the sum of two non-verbal tasks and 2 verbal tasks of the WISC-IV). Summary scores are presented in Table below. The ASD group included one female, the ADHD group consisted entirely of males, and the typical group consisted of 9 males, and 11 females.

Typically developing and ASD matched sample –

Twenty individuals with autism were matched to 20 typically developing individuals on non-verbal ability and total WISC raw score (short-version). Summary of scores presented in Table 2.4 below.

Table 2.4: *Typical and ASD matched sample descriptives (mean with standard deviation in brackets).*

	N	*CA*	*Non-verbal score*	*WISC raw score*	*Visual preference*	*Tactile Preference*
Typical	20	8.75 (1.12)	39.45 (15.32)	79.30 (25.69)	6.30 (3.53)	6.70 (3.54)
ASD	20	10.60 (2.11)	38.60 (14.05)	70.05 (24.86)	6.95 (3.39)	6.00 (2.90)

No significant group difference was found in non-verbal ability (t(38) = .18, p = .86), nor in WISC raw score (t(38) = 1.16, p = .25).

Complexity preference

A 2x2 ANOVA found no significant main effect of complexity (F(1,38) = .18, p = .677). No significant group difference in complexity preference was found (F(1,38) = .001, p = .976). No significant interaction was found between visual and tactile complexity preference and group (F(1,38) = 1.06, p = .309).

Typically developing, ASD and ADHD matched sample

Individuals from the ASD and ADHD group were matched to typical individuals on total WISC-IV raw score (for two verbal and two non-verbal subscales, and on non-verbal score). Summary descriptives for matched samples are in Table 2.5 below.

Table 2.5: *Sample descriptives including mean visual and tactile preference (standard deviation in brackets).*

	N	*CA*	*Non-verbal score*	*WISC raw score*	*Visual preference*	*Tactile Preference*
Typical	22	9.09 (1.54)	46.05 (18.00)	88.59 (28.80)	7.27 (3.01)	4.91 (3.26)
ASD	11	10.55 (1.97)	46.73 (10.78)	80.73 (25.08)	6.00 (3.44)	5.82 (2.68)
ADHD	11	11.64 (1.50)	48.64 (20.54)	89.64 (30.98)	6.45 (3.96)	6.45 (3.39)

A one-way ANOVA revealed no difference in WISC raw score across groups, (F(2,43) = .347, *p* = .71), nor for non-verbal score (F(2,43) = .083, *p* = .92).

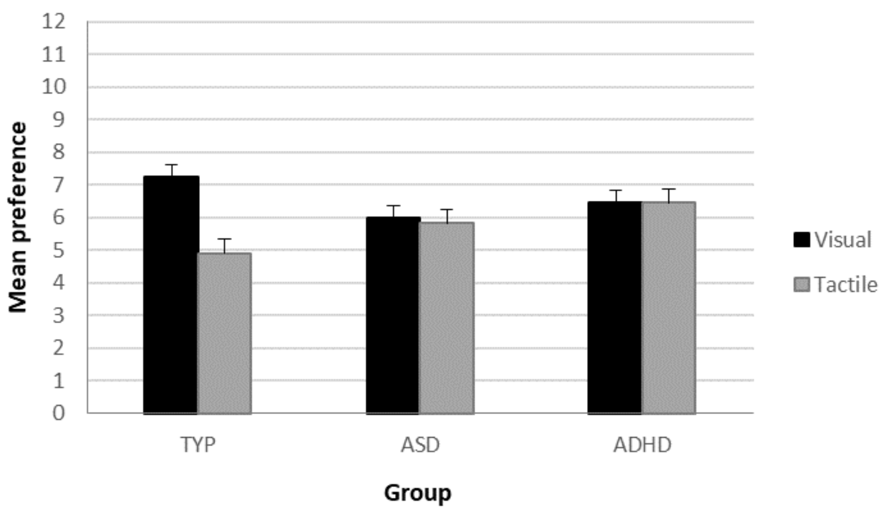


Figure 2.12: *Average preference score for complexity for each participant group. Error bars represent standard error.*

A mixed model ANOVA found no main effect of complexity preference (F(1,41) = 1.84, *p* = .182). No main effect of group was found (F(2,41) = .127, *p* = .881). No significant interaction was found between group and preference (F(2,41) = 1.84, *p* = .172). Therefore, both comparison groups have the same preference for visual and tactile complexity as the typical group.

Correlation between tactile and visual complexity preference for each sample separately

No correlation was found between tactile and visual complexity preference for the typically developing sample (r(51) =.23, *p* = .096). There was a significant positive correlation between tactile and visual complexity in the ASD (r(13) = .76, *p* = .001) and ADHD sample (r(9) = .67, *p* = .024).

Exploring Personality, Anxiety and Complexity preference for each sample separately

Typical sample:

No correlation was found between *complexity preference* (total score for visual and tactile complexity preference) and General anxiety (r(51) = .01, *p* = .945), no correlation between *complexity preference* and Extraversion (r(51) = .04, *p* = .784), nor for *complexity preference* and Neuroticism (r(51) = .21, *p* = .135).

ASD sample:

No correlation was found between *complexity preference* (total score for visual and tactile complexity preference) and General anxiety (r(13) = -.19, *p* = .489), no correlation between *complexity preference* and Extraversion (r(13) = .15, *p* = .589), nor for *complexity preference* and Neuroticism (r(13) = .14, *p* = .606).

No correlation was found between *complexity preference* (total score for visual and tactile complexity preference) and General anxiety (r(9) = .07, *p* = .865), no correlation between *complexity preference* and Extraversion (r(9) = -.29, *p* = .486), nor for *complexity preference* and Neuroticism (r(9) = -.43, *p* = .289).

Exploring Personality, Anxiety and Complexity preference for matched samples

ASD and Typical sample:

No significant group difference was found for Extraversion (t(26) = 1.77, *p* = .089), nor for General Anxiety (t(26) = -.39, *p* = .70). There was a significant difference in Neuroticism with a higher mean score in the ASD group (M = 91.00) compared to the typical group (M = 71.93), t(26) = -2.78, *p* = .01.

ADHD and TYP:

No significant differences found between the typical and ADHD group for Extraversion ($t(12) = .41$, $p = .693$), Neuroticism ($t(12) = -.31$, $p = .764$), nor General Anxiety ($t(12) = -.131$, $p = .898$).

2.7 Discussion

Study 1 aimed to explore texture preferences and aversions across typical and atypical development through means of a texture preference questionnaire. The results from the Tactile Preference and Aversion Questionnaire (TPAQ) indicate that preferences and aversions appeared to be similar for individuals with autism and typically developing individuals. In particular, the typically developing group and autistic group have almost identical patterns of preferences and aversions. These findings are contrary to what we would have expected based on the anecdotal reports (e.g. Larsen, 1982; Sears, 1981) and evidence that individual with ASD have extreme aversions to / fascinations with certain textures (e.g. Grandin, 1992). These results are particularly surprising given the significant differences found in the sensory patterns between typically developing individuals and those with autism, when examining the results from the Sensory Profile. Comparison across the four quadrants clearly showed that individuals with autism score predominantly 'more than others' (hyper-responsive) for each quadrant; Low Registration (Q1), Sensation Seeking (Q2), Sensory Sensitivity (Q3) and Sensation Avoiding (Q4). In addition, Study 2 aimed to determine whether *texture complexity* could account for differences in texture preference between typically developing individuals and those with ASD. Contrary to the prediction that individuals with ASD would prefer less complex texture, no group differences in complexity preference were found.

The results from the TPAQ revealed that individuals with ADHD have a different pattern of preferences to typically developing individuals. Individuals with ADHD rated some textures as more aversive compared to typically developing individuals with greater standard deviations in their ratings. This is consistent with the findings of Mangeot et al. (2001) who found evidence of more variability in sensory defensiveness in children with ADHD and concluded that there were two sub-groups in individuals with ADHD: those with and those without sensory defensiveness. These findings also lend support to Bauer (1977), who proposed that hyperactivity in individuals with ADHD resulted in increased tactile defensiveness, which would support the findings in the TPAQ of higher level of aversion in the ADHD sample. However, it is not clear whether the increased aversion would result in poorer discriminatory ability, or whether the defensiveness and discrimination are separate expressions of tactile modulation dysfunction, (Royeen and Lane, 1991).

The study also aimed to explore patterns of preferences and aversions across age. There were significant age differences found in the typically developing group. The pattern of texture preference across age appears to be consistent with the evidence that in early development preference is related to novelty (e.g. Bushnell and Boudreau, 1991; Sireteanu, Encke, & Bachert, 2005). That is, all texture dimensions are rated more favourably in young children, then preference ratings become increasingly more neutral with older age groups. By comparison, the TPAQ results revealed that texture preferences are consistent across ages in individuals with autism. These findings support Leekam et al. (2007) who demonstrated no significant differences across age and IQ level for number of tactile symptoms in individuals with autism. Research has demonstrated tactile defensiveness in infants (Case-Smith, Butcher & Reed, 1999; Baranek, 1999) and adults (Kinnealey, Oliver &Wilbarger, 1995). There is evidence of reduced sensory defensiveness with age (Baranek & Berkson, 1994), but this difference could perhaps be explained by a difference in coping strategies. For example, the avoidance of texture known to cause aversion, but preference per se does not change, i.e. the individual is still tactile defensive. However, this result needs to be interpreted with caution as if the sample was bigger and sphericity assumed then there may be significant age differences, particularly with rough texture preference, which changed from a clear preference in early development to a neutral rating with age.

Additionally, it appears that preferences and aversions fall on specific texture dimensions, particularly preference for smoothness, which supports previous literature (Ekman, Hosman, & Lindstrom, 1965). The results show that all participant groups prefer soft and smooth over hard and rough, regardless of age. Roughness is consistently rated more as an aversion than a preference across all participant groups. Although not a recognised texture dimension, preference ratings for ‘sticky-slippery’ was found to significantly different between participant groups, with individuals with autism and ADHD most aversive to ‘sticky-slippery’ compared to typically developing individuals.

Another possible limitation of the TPAQ is that it may have been difficult for parents to comment on texture preference given the young age of their child. Infants are naturally curious and often explore textures manually and orally. It may have been difficult for parents to differentiate this exploratory behaviour with general preference. However, given the anecdotal reports from parents whose children experience extreme preferences or aversions, if such apparent difference in texture preference exist, the TPAQ would be able to expose these differences.
Further examination of the open text comments from the TPAQ revealed that *cotton wool* and *clothing labels* are the most frequently mentioned texture in both the typical and atypical group (ASD and individuals with other sensory difficulties). In the typical group there were 69 comments, of which 3 comments indicated ‘extreme’ preference (1) or aversion (2) to labels, and 6 comments indicated ‘extreme’ aversion (4) or preference (2) to cotton wool. In the atypical group there were 39 comments, of which 6 indicated ‘extreme’ preference (2) or aversion (4) to labels, and only 2 comments indicated ‘extreme’ preference (1) or aversion (1) to cotton wool. Therefore, clothing labels seem to be particularly problematic for the atypical group, and cotton wool appears to be more problematic for the typical group. No other texture is consistently rated as either a preference or aversion. An aversion to clothing labels is commonly mentioned by those parents with children who have sensory processing difficulties.

There are recognised limitations of parent reports (Rothbart & Goldsmith, 1985), however they are economical and practical which enables large sampling and young children (especially those with developmental disabilities) may lack the cognitive capacity to self-report and report on such issues. There is support that parent reports on sensory symptoms are an accurate measure when compared with assessment (Rogers, Hepburn, & Wehner, 2003). A questionnaire was reasonable for studying texture preferences as it is not a sensitive subject for parents to comment on, and parents observe their children in many different situations across time and therefore are likely to observe unusual behaviour(s) that would otherwise be unable to assess, e.g. a particular texture that causes aversive reaction might be avoided and thus the unusual behaviour becomes less frequent and may be missed under controlled experimental conditions. Use of a rating scale may account for the lack of extreme ratings as this is a generally accepted flaw with Likert Scale (e.g.

Ray, 1990; Gardner, 1995), or they may genuinely be few extreme preferences and aversions. This is unexpected when considering the anecdotal reports of 'extreme' avoidance and / or fascination with texture. Averaged ratings across participants for each texture may also contribute to not finding extreme texture preference or aversion.

The TPAQ did show good internal reliability, tested a wide age range and various participant groups. The results help to address the lack of specific information on other parent reports on sensory defensiveness (SP; Dunn, 1994; SEQ; Baranek, 1999; Provost & Oetter, 1993), specifically about the types of materials that cause aversive reactions. The questionnaire achieved the aim of creating a baseline of preferences and aversions across typical and atypical development through recruiting a large and varied sample. By doing so has added to research on texture preferences and aversions across typical and atypical development.

The results from the Complexity Preference Study (Study 2) found no difference in preference between typically developing individuals and those with ASD. Perhaps the materials used did not sufficiently constitute a complex stimulus, or perhaps there is no real difference in preference. Berlyne (1960) suggested a number of pattern characteristics and dimensions are related to stimulus complexity, for example symmetry, repetition of parts and number of different parts. Future studies should control for these elements when designing materials. When comparing study results, there are substantial differences in the materials used, i.e. not only in whether the stimulus is visual or tactile, but in how 'complexity' has been defined. For example, in Berlyne's (1963) study on pattern regularity, the less irregular (LI) stimuli look remarkably like the 'High Complex' wall paper material in my study. Therefore, despite the materials being independently pre-ranked on level of complexity, they would be considered less irregular and less complex in Berlyne's study. It is therefore difficult to make a direct comparison about the relationship between complexity and preference. It is also important to note that all the literature on preference for complexity is based on visual stimuli. It is not known what this relationship between preference and complexity might be in other modalities. It is also not clear how complexity of a visual stimulus would transfer to a tactile texture stimulus, i.e. perhaps texture complexity has more to do with frequency vibration than number of different parts.
In addition, asking children to pick 'which one they like', may be governed by judgements of how "interesting" or "amusing" the stimulus is. Children may also have preconceived notions of

what ought to be preferred. Research has found that an increase in complexity results in an increase in 'interestingness' and a decrease in 'pleasantness' (e.g. Terwilliger, 1963). These findings illustrate that 'interestingness', 'pleasantness' and 'preference' are related to complexity in different ways. Future studies should explore differences in these subjective ratings of complexity. It was not possible to do so in this study given the ability of the atypical sample. Given the suggestion that individuals have a preferred level of complexity (Dember & Earl, 1957), future studies could control for this individual difference. This relates to the idea of a complexity-simplicity as a personality dimension (Eisenman, 1966), with individuals who prefer complexity preferring asymmetrical figures, and those who prefer simplicity preferring symmetry (Berlyne, 1963). However, the relationship between symmetry and complexity is uncertain, with research indicating that individuals' rate symmetry favourably regardless of complexity preference (Eisenman & Rappaport, 1967). The relationship between these variables has only been explored in typical populations. Future research should attempt to disentangle these factors and further explore these relationships in atypical samples.

No difference was found between typical and ASD groups in general anxiety, despite the literature suggesting high prevalence of anxiety in children and adolescents with autism (White, Oswald, Ollendick & Scahill, 2009; MacNeil, Lopes & Minnes, 2009), and the evidence to suggest comorbid Social Anxiety Disorder with ASD (Maddox & White, 2015). Ayres (1972) theorised that anxiety results from hypersensitivity to stimuli in the environment. More recently, Pfeiffer et al. (2005) found a significant link between sensory over-responsivity and anxiety in children (aged 6-16 years) diagnosed with Asperger Syndrome. Despite individuals with ASD in my study sample having different sensory profiles to typically developing individuals, no difference was found in general anxiety.

Our results also found no difference in general anxiety between typically developing individuals and those individuals with ADHD. Anxiety is a co-morbid condition that is associated with ADHD in approximately 25-33 % of individuals diagnosed with ADHD (Schatz & Rostain, 2006). In addition, Lane, Reynolds and Thacker (2010) found significant correlations between sensory over-responsivity and anxiety in typically developing children and children with ADHD. With regards to tactile sensitivity, Parush et al. (2007) found significant differences in central processing of somatosensory input (EEG recordings) in children with ADHD and tactile sensory over-responsivity compared to those individuals with ADHD and no tactile over-responsivity. A larger sample of individuals with ADHD would allow for exploration of subsets of individuals with ADHD who specifically have tactile over-responsivity. By doing so would allow for better examination of the relationship between anxiety and tactile sensitivity in ADHD.

Study 2 found no correlation between Extraversion and complexity preference for any of the participant groups, despite the literature suggesting that extraverts would prefer more complex stimuli (Bartol & Martin, 1974). In support of previous research there was a significant difference found in Neuroticism with higher scores in the ASD group compared to the typical group (Schriber, Robins, & Solomon, 2014). No group differences were found in Extraversion nor Neuroticism between typically developing individuals and those with ADHD. Previous research has found that ADHD was associated with low Conscientiousness, low Agreeableness and Neuroticism (Nigg et al., 2002). The young age range of the participants with ADHD in Study 2 and the small sample size may account for the lack of significant differences in personality traits between typically developing children and those diagnosed with ADHD.

Conclusion

Following the findings of the TPAQ, the question remains whether differences in tactile preferences and aversions reported in the literature are due to differences in *sensitivity to texture* and not preference or aversion per se. To address this, the next study was designed (Chapter 3) to examine possible differences in tactile sensitivity in the discrimination of fine texture. Research has indicated that individuals diagnosed with autism have enhanced auditory (Bettison, 1996) and visual (e.g. Bryson, Wainwright-Sharp & Smith, 1990) perception, but no study to date has demonstrated enhanced discrimination in the tactile modality in individuals with autism. O'Riordan and Passetti (2006) proposed that enhanced visual and auditory processing ability exhibited in individuals with autism may be generalised to other modalities, i.e. to explain unusual tactile processing. However, in their study they did not find enhanced tactile processing in individuals with autism. They did not specifically examine fine tactile discrimination, which may account for the lack of significant results in their study. They do not specify the exact grades of sandpaper that were used, but only had four texture grids ranging from 'coarse to fine'. The very small range of sandpaper grades used contributes to the lack of sensitivity in the methodology and could account for the non-significant difference in tactile discrimination. The questions that follow are 1) whether tactile hypersensitivity would result in aversion to or fascination with fine texture, i.e. whether hypersensitivity refers to tolerance of texture (a lower frequency threshold), and / or 2) whether tactile hypersensitivity refers to discriminatory ability, i.e. does hypersensitivity result in better fine texture discrimination. The following chapter will explore tactile sensitivity in a fine texture discrimination task.

Chapter three

Texture Perception and Sensitivity

3.1. Introduction

In the previous chapter, we explored texture preferences in typical and atypical development. Contrary to the expectation, individuals with autism and ADHD have the same texture preferences to typically developing individuals. Differences in texture preference was also not related to the complexity of texture. It was concluded that perhaps the reported aversions or unusual reactions to texture by individuals with autism may be due to a heightened sensitivity to sensory stimulation, a frequently documented symptom in ASD (e.g. Crane Goddard, Pring, 2009; Lane, Molloy & Bishop, 2014; Tavassoli, Miller, Schoen, Nielson & Barron-Cohen, 2014). Our sense of touch is particularly useful for discriminating fine texture differences. Research on roughness perception has received the most attention, with typically developing individuals being able to accurately discriminate fine texture differences. Little research exists exploring texture discrimination in atypical development. Increasing evidence has given support for the numerous anecdotal and parent-reports of heightened sensitivity in autism, and over-responsivity in ADHD (as mentioned in Chapter 1). The unusual sensory response to tactile stimulation observed in individuals with autism and ADHD may possibly be explained by 'heightened sensitivity'. Sensory seeking and sensory avoiding (hyper / hypo- responsivity) behaviours often exhibited in individuals diagnosed with autism and those individuals with ADHD may contribute to accuracy of fine texture discrimination.

The following study aims to explore any perceptual differences in fine texture discrimination between typically developing individuals and those diagnosed with autism or ADHD, i.e. tactile sensitivity to texture. It is predicted that individuals with autism, given their *heightened sensitivity* to sensory stimuli, would be more accurate at fine texture discrimination. Individuals with ADHD, who tend to be *over-responsive*, may also be more accurate at fine texture discrimination than the typically developing group.

3.2 Tactual texture perception

Until recently, research into the way materials or material parameters are perceived by means of touch has been limited. Most psychological studies examining tactile texture perception have been conducted using artificial stimuli, such as dotted surfaces, grating patterns or abrasive papers. The perception of more ‘natural’ materials, occurring in every day context, has received less attention. Most previous studies have focused on a very specific kind of material (e.g. metal gratings, or sandpaper) or have used only a small number of different materials, (Tiest & Kappers, 2006). In addition, the focus has been on the perception of roughness which has received the most systematic attention, with particular interest in the role that vibration cues play in roughness perception, (Picard, Dacremont, Valentin, and Giboreau, 2003). Unfortunately, little is known about other aspects of texture perception.

Almost all the work to date has been psychological and psychophysical in nature. The early work (Katz, 1952; Stevens and Harris, 1962) used a variety of stimulus surfaces, such as different quality papers. However, these materials varied along many unspecified or inaccurately measured dimensions. More recent work by Lederman, Ganeshan, & Ellis (1996) has investigated the nature of roughness perception in a systematic way by using metal gratings that vary along several specified and well-controlled dimensions.

Katz (1925/1989) argued that perception of texture relies on two types of cues, i.e. spatial and temporal. He suggested that the geometrical properties of a texture, such as the size, shape, density and arrangements of the surface elements, give rise to the spatial cues of a texture. Information about these spatial properties will only constitute a texture cue if it is registered by the somatosensory system. Katz differentiated between registration of coarse and fine textures. Katz claimed that such registration occurs with coarse textures where their elements can be individually discernible. However, some textures are so fine that their elements are not discernible from each other. Katz argued that under these circumstances it is doubtful that spatial cues are used to perceive texture and argued for the importance of relative movement across the surface of the texture. Katz hypothesised that vibrotraction plays a role in the discrimination and psychological scaling of fine textures, as the elements are too small and closely spaced to be processed spatially without movement. Katz claimed that the perception of fine textures is possible because of the ability to detect and discriminate the vibrations that are produced when the skin moves across a surface (active touch), or when a surface moves across the skin (passive touch). The idea that there are two different types of encoding for texture perception, i.e. spatial encoding for coarse textures and temporal (vibrotactile) encoding for fine textures, has been referred to as the *duplex theory of tactile texture perception.* The theory emphasises the difference in fine and rough texture perception. Thus fine and rough texture may not be perceived in the same way. It could be suggested that the reported differences in texture preference may be due to perceptual differences of rough and smooth stimuli.

A more recent experiment by Hollins and Risner (2000) where participants were asked to estimate the roughness of a set of 12 sandpapers, supported Katz suggestion. Judgements were made under both stationery and moving conditions and the findings revealed that the elimination of movement, and therefore vibration, had no effect on the discrimination of coarse texture, but significantly reduced the discrimination of fine surfaces. Slightly different to Katz position as he claimed that relative motion is imperative to roughness perception, whereas Hollins and Risner demonstrated that movement is not needed for the discrimination of coarse texture. Gibson (1962) too has argued that vibratory frequency is the critical determinant of roughness perception. On the other hand, Taylor and Lederman (1975) have argued that vibration per se is not a necessary condition for the perception of roughness. They discovered that felt roughness was best predicted by the amount of instantaneous skin displacement, which is determined primarily by groove and ridge width and finger force. Findings revealed that perceived roughness increased with increasing force. In addition, they found that hand speed had a negligible effect, but faster hand speed resulted in a decrease in perceived roughness. Taylor and Lederman (1975) claimed that this was because there is less time for the skin to deform within the grooves, and therefore perceived roughness is reduced. Therefore, concluded that temporal factors play a minor role, if any at all, in the tactual perception of roughness, and more important was the spatial information.

In support of Taylor and Lederman's (1975) *mechanical* model of tactual roughness perception, Lederman (1983) demonstrated that tactual roughness perception of linear gratings was not affected by either spatial period or to the difference between groove and ridge. Lederman also noted that there were negligible effects on perceived roughness when varying the relative speed of motion between skin and surface, regardless of whether active or passive touch was used.

Therefore, Lederman argued against a temporal coding theory of roughness perception, i.e. argued that the dynamic aspects of the signal (e.g. the rate of skin displacement) were not a necessary component to the perception of roughness. Supporting these findings, Hollins, Faldowski, Rao, & Young (1993) used a set of surfaces that were precisely defined geometrical textures made by etching silicon wafers and found that vibration (temporal coding) was essential to the perception of fine surfaces, but not to coarse surfaces. Highlighting the fundamental role of vibration in fine texture discrimination, Hollins Bensmaia & Washburn (2001) demonstrated that pre-exposure to vibration had detrimental effect on fine texture discrimination (made them indiscernible) but had no effect on the discrimination of coarse textures. These results emphasise that fine and rough texture may not be perceived in the same way. It could be suggested that any differences in texture discrimination may be due to perceptual differences in the ability to discriminate rough and smooth stimuli between typically developing individuals and those with autism or ADHD.

3.3 Sensory abnormalities and hypersensitivity in autism

The first description of autism highlighted the hypersensitivity of senses, in particular touch, taste and smell, (Asperger, 1944, as cited in Van Krevelen, 1971). With increasing evidence to support the abundance of anecdotal reports, it is now accepted that individuals with ASD experience heightened sensitivity. Hypersensitivity to sensory stimuli is frequently documented symptom in ASD, primarily through parent and self-reports (Crane, Goddard & Pring, 2009; Lane, Molloy & Bishop, 2014; Tavassoli, Miller, Schoen, Nielson & Baron-Cohen, 2014).

Sensory abnormalities are prominent in the tactile domain and are reported to be more debilitating by parents of individuals with unusual sensory sensitivities (Kinnealey, Oliver & Wilbarger, 1995). As discussed in Chapter 1, sensory abnormalities in the tactile domain have been defined as tactile defensiveness, i.e. the observable aversive or negative behavioural response to certain types of tactile stimuli (Royeen & Lane, 1991). Symptoms of tactile defensiveness include over-sensitivity (hyper-responsiveness) to certain textures (Case-Smith, 1991). Tactile defensiveness is considered hyper-responsivity to tactile stimulation and may possibly be associated with heightened sensitivity to touch in autism, (Royeen, 1985). Approximately 50% of adults with ASD and 52% of children with ASD have been reported to be hypersensitive to touch (Harrison & Hare, 2004; Bromley, Hare, Davison & Emerson, 2004 respectively).

Tactile hypersensitivity

An explanation of hypersensitivity in ASD was proposed by Blakemore et al. (2006), which suggests that sensitivity to vibrotactile stimuli occurs at two different frequencies (30 – 200 Hz). These two frequencies are known to stimulate two different mechanoreceptors in the skin. High frequency vibration (200 Hz) stimulates Pacinian corpuscles and activates FA11 fibres, whereas lower frequency vibration (30 Hz) stimulates Meissner corpuscles and activates SA1 fibres. Pacinian corpuscles are involved in the discrimination of fine surface textures and other moving stimuli that produce high frequency vibration of the skin. Blakemore et al. found that tactile perception threshold at 200 Hz was significantly lower in individuals with Aspergers syndrome (AS) than in the control group. That is, the AS group were hypersensitive to vibratory stimuli of 200 Hz, but there was no significant difference found between AS and control for tactile threshold of 30 Hz. Results demonstrate that AS individuals had significantly lower tactile perception thresholds (were hypersensitive) to vibrotactile stimulus at 200 Hz, i.e. they were hypersensitive to high frequency, but not to low frequency vibrotactile stimulation. As suggested by Katz (1989) the tactile discrimination of fine texture requires high frequency vibration, whereas the discrimination of coarse texture does not require movement (vibration). The specific hypersensitivity to higher frequency vibrotactile stimuli found in individuals with AS suggests a hypersensitivity (over-responsivity) to fine textures. A difference in texture preference between typical and atypical development may possibly be explained by differences in sensitivity and therefore preference to fine texture.

A theoretical explanation for the hypersensitivity experienced in autism, is the Theory of Weak Central Coherence (Happé & Frith, 2006), which proposes that in autism there is a bias in information processing in that individual stimuli are thoroughly analysed but not sufficiently integrated into a coherent meaningful whole or Gestalt, (Blakemore et al., 2006). Therefore, hypersensitivity could possibly be explained as the result of impaired top-down modulation of incoming stimuli. In typical development, top-down modulation in the brain acts as a filter so that known stimuli do not have to be processed as if they were new stimuli, therefore preventing information overload. It could be assumed that if this type of information processing were impaired in autism then all incoming stimuli would be processed as new and unexpected, resulting in over-sensitivity to all stimuli (an aversion). That is, in terms of texture, detecting individual texture components and not perceiving a unitary texture. The question remains, would the result be increased sensitivity to individual components therefore resulting in better discrimination or would this result in the texture being perceived as rougher than it is? The first question will be addressed in the following study. In support of the suggestion that hypersensitivity experienced in autism could be explained by Weak Central Coherence (WCC; Happe & Frith, 2006), Pellicano and Burr (2012) proposed the idea of attenuated Bayesian priors (hypo-priors) which suggests perception in autism is less modulated by prior experience, and therefore have the tendency to perceive stimuli as more accurate. However, these proposals do not account for the fact that individuals with autism are aversive to some stimuli and not to others. The above theory would presume that all incoming stimuli would be processed as unfamiliar and this would produce exaggerated/ over-sensitive response, and in the domain of touch many of the anecdotal reports are suggestive of hypersensitivity to certain stimuli and not to others. However, recent research supports the idea of heightened sensitivity in autism. Takarae, Sablich, White and Sweeney (2016) examined visual neural responses to sensory stimulation and report evidence for heightened neural excitability in the sensory cortex in individuals with ASD. The authors suggest that this atypical neurological processing may be related to hyper-responsivity observed in ASD.

Baranek and Berkson (1994) presented evidence to suggest that tactile defensiveness is associated with over-sensitivity (hypersensitivity) to tactile stimulation and slower habituation rates to repeated tactile stimulation. These would lend support to the proposal that the Theory of Weak Central Coherence could explain hypersensitivity to texture in individuals who exhibit tactile defensiveness. This could possibly explain why infants who later exhibit tactile defensiveness avoid exploration (Larsen, 1982). Due to oversensitivity and lack of habituation the stimulus would continuously be experienced as novel and perhaps be over arousing. Hutt, Hutt, Lee and Ounsted (1964) present a theory of over arousal in individuals with autism that would support this suggestion. Hutt et al. proposed that physiological over-arousal, whereby the brainstem reticular formation was sustained at a chronically high and inflexible level, led to blocking of the neural sensory pathways to prevent further over-arousal. This in turn led to avoidance of novelty, i.e. sameness provided a means of avoiding increased stimulation.

3.4 Enhanced perceptual functioning

O'Riordan and Passetti (2006) propose that enhanced visual (Bryson, Wainwright-Sharp & Smith, 1990) and enhanced auditory (Bettison, 1996) processing ability exhibited in individuals with autism may be generalised to other modalities i.e. to explain unusual tactile processing, such as tactile defensiveness. Jolliffe and Baron-Cohen (1997) found that autistic individuals had enhanced ability to discriminate between visual stimuli in embedded images task. Superior auditory processing of pitch has also been found in autistic individuals relative to controls (e.g. Mottron et al., 2006; Heaton, Hermelin & Pring, 1998), in pitch discrimination (Bonel et al.,2003), and processing speech (Jarvinen-Pasley et al., 2008). A possible explanation to these findings was put forward by Remington, Swettenham, Campbell and Coleman (2009) who examined the effect of perceptual load on attention. They found that individuals with ASD required higher levels of perceptual load to successfully ignore irrelevant distractors compared to the control group. They authors suggest that these results indicate enhanced perceptual load in individuals with ASD. O'Riordan and Passetti (2006) suggest that enhanced pitch processing in autism may be the result of enhanced auditory discrimination, which could result in overload and thus distress to some sounds. They propose a general cognitive style that could possibly explain tactile over-sensitivity / tactile defensiveness by means of enhanced tactile discrimination. However, O'Riordan and Passetti (2006) failed to find a significant difference in a tactile discrimination task between controls and individuals with autism. Participants were asked to discriminate the roughness of four different grades of sandpaper. Given that there were only four different sandpaper grits used, perhaps a lack of task sensitivity could explain the non-significant findings.

Mottron, Dawson, Soulieres, Hubert and Burack's (2006) Enhanced Perceptual Functioning (EPF) model was prosed as an alternative model of perceptual functioning in autism to the theory of Weak Central Coherence (WCC; Happe & Frith, 2006). The EPF was proposed as a model to account for a number of unusual perceptual processing differences in autism - as a framework to understand perceptual characteristics of autism as superior processing of local properties, i.e. low-level perceptual operations. Findings of superior perceptual discrimination in autism support hyper-functioning / superior perceptual processing of lowlevel properties (Plaisted et al., 1998). More recent research indicates a significant positive relationship between autistic traits and sensory over-responsivity (Tavassoli, Miller, Schoen, Nielsen & Baron-Cohen, 2013). Therefore, it is plausible that tactile processing in autism might be understood in the context of enhanced discrimination, e.g. heightened sensitivity to fine texture differences.

3.5 ADHD and sensory over-responsivity

Individuals with ADHD exhibit behaviours of impulsivity, inattention and hyperactivity which affect daily functioning (Barkley, 1998). Emotional responses associated with Sensory Modulation Dysfunction (Ayres, 1979), including explosive, aggressive behaviours and an inability to regulate the intensity and duration of interaction with others, overlap with behaviours described in the ADHD phenotype. The overlap in associated behaviours emphasises the importance of exploring sensory differences in ADHD (Greenspan & Wieder, 1993) yet there is limited research on sensory processing in ADHD.

Individuals with ADHD display differences in sensory reactivity on several difference measures. Mangeot, Miller, McIntosh, McGrath-Clarke et al. (2001) measured electrodermal reaching in individuals with ADHD and reported greater abnormalities in sensory modulation compared to a typical sample on both physiological and parent-report measures. Parush, Sohmer, Steinberg and Kaitz (2007) explored somatosensory function in boys with ADHD and tactile defensiveness and found significant differences from the typical group on all measures, including somatosensory evoked potential responses and self-ratings. On a parentreport measure (Sensory Profile) children with ADHD demonstrated significant differences in sensory responsiveness to typical matches (Yochmou, Parush & Ornoy, 2004). This reported difference in response is consistent with several earlier studies (e.g. Ayres, 1964; Bauer, 1977; Papadopoulos & Staley, 1997; Parush et al. 1997).

Consistent with research in autism, individuals with ADHD are reported to demonstrate over-responsivity to sensory stimuli more frequently than typically developing children (Dunn, 1999), and to be overly sensitive to sensory stimuli and environmental changes in infancy (Kaplan et al. 1994). In later development, sensory over-responsivity in ADHD is associated with poor social emotional outcomes (Mangeot et al. 2001), lower performance at school (Dunn & Bennett, 2002), and less engagement in leisure activities (Engel-Yeger & Ziv-On, 2011). These findings highlighting the lack of syndrome specificity of sensory processing difficulties. Similarly, to research in autism, studies are inconsistent in demonstrating physiological differences between ADHD and typically developing individuals (Iaboni, Douglas & Ditto, 1997; Barkley, 1998), which suggests that perhaps they are not a homogenous group in terms of their sensory responses. This supports the finding in autism research of both hyper and hypo responsivity across different modalities within groups (e.g. Foss-Feig, Heacock & Cascio, 2012; Boyd et al. 2010). The within syndrome heterogeneity therefore provides a challenge for understanding sensory processing difficulties within and across different clinical groups.

Introduction to the following study exploring heightened sensitivity

No significant differences in texture preference were found in the Study 1, but in the following study *hypersensitivity* is proposed as a possible explanation to reported differences in tactile responses between typical and atypical development. The aim of the study was to determine whether individuals with autism exhibit enhanced tactile processing. Given the evidence of heightened sensitivity in autism, the prediction is that individuals with autism will be more accurate at tactile discrimination of fine texture, than typically developing individuals. With increasing evidence that individuals with ADHD exhibit hyper-responsivity, it was also predicted that individuals with ADHD will be more accurate at discrimination than typically developing individuals.

3.6 Development of the tactile discrimination task

The texture discrimination task was developed over two pilot studies to determine the range in texture gradient needed to create varying levels of difficulty and to determine the number of trials that children would be able to comfortably complete. Given the ability of the clinical sample, trial numbers had to be kept low.

3.6.1 *Pilot Study 3.1.*

Method

Participants:

Ten adults completed the task, 6 females (mean age 33 years) and 4 males (mean age 35 years). Participants volunteered to take part and were all from Newcastle-upon-Tyne. Ethics for the study was approved by the local ethics committee at Newcastle University.

Materials:

The sandpaper sheets were presented in pairs on card. Sheets were 3 x 4 cm in size. Sandpaper grit values used were 60, 80, 100, 120, 150, 180, 320 and 400. Average particle sizes were 296, 201, 162, 125, 100, 82, 46.2, and 35 micrometres respectively. All sandpaper used adhered to ISO/FEPA (Federation of European Producers of Abrasives) standards.

There were ten comparison pairs, which varied in level of difficulty. There were three levels of difficulty- Easy, Medium and Hard Level of difficulty was determined by the percentage difference in average particle size for each pair. Easy comparison pairs ranged between 56% and 66% difference, Medium comparison pairs ranged between 26% and 38% difference, and Hard comparison pairs ranged between 19% and 21% difference. For example, in the Medium comparison pair 60-80 (particle size 296 and 201 respectively), the percentage difference in average particle size is [(296-201) / (296+201/2)]*100 = 38%. There were three **Same** comparison pairs, two **Easy** comparison pairs, three **Medium** comparison pairs and two **Hard** comparison pairs (refer to Table 1 below comparison trials).

Table 3.1: Trial comparisons for each level of difficulty.

	Trial comparison pairs		
Same	60-60	150-150	400-400
Easy	100-180	180-320	
Medium	60-80	100-120	320-400
Hard	80-100	150-180	

Procedure:

The task was a forced-choice task to decide whether the two sheets were the *same or different*. Participants were presented with 10 comparison pairs, each presented randomly three times (a total of 30 trials). Vision was occluded during presentation. Participants were required to use only their index finger of their writing hand. Participants could alternate between comparison sheets as many times as needed to make a decision per trial. Participants were given a maximum of one minute per trial. The task lasted approximately 15 minutes.

Data Analysis: Accuracy was coded as 1 for correct identification of whether the pair presented was the same or different, and 0 for incorrect responses.

Results

Typical adults-

Table 3.2*: Mean and standard deviation (SD) for proportion correct in each level of difficulty*.

	Level of Difficulty			
	Same	Easy	Medium	Hard
Mean	.84	.98	.42	.27
SD	.36	.15	.50	.44

The descriptive statistics show that with increased level of difficulty, mean accuracy decreases. Most errors were made in the 'Hard' comparisons and least errors in 'Easy' comparisons.

The data presented in Table 3.1 were analysed using one-way repeated measures ANOVA for within-subjects designs to examine the effect of level of difficulty on accuracy. A significant effect of level of difficulty was found, F (3, 267) = 70.79, p <.001. All pairwise comparisons were found to be significant at p < .01. The effect size was large with partial eta squared of .74.

Pilot 1 conclusion

The pilot with adults served *only* to determine whether the discrepancy between gradients of texture would be too easy to discriminate, and to check that there would be sufficient difference in performance across the three levels of difficulty. The results indicate that there is minor difference in performance between the medium and hard level of difficulty. Therefore, to increase the discrepancy across levels, grit value 280 was added to create new texture pairs. An additional comparison pair was added to the Hard level (280-320) and to the Easy level (60-100).

3.6.2 *Pilot Study 3.2*

The purpose of the second pilot study was to test the new texture pairs with a sample of typical and atypical children.

Method

Participants:

Thirty typically developing individuals (mean CA = 8.7, age range 5 to 14 years) and 10 individuals diagnosed with autism (mean CA = 8.2, age range 7 to 9 years) were recruited from local schools in the North East of England. Age information was missing for two typical developing individuals (remaining sample mean age = 8.36, std = 2.59), and due to incomplete data and / or missing WISC information, analysis was conducted on only 8 individuals with ASD (mean age = 9.25, std = 1.83). There were two females and six males in the ASD group. In the typical group there were 13 males and 15 females. Ethics for the study was approved by the local ethics committee at Newcastle University.

Materials:

The sandpaper sheets were presented in pairs on card. Sheets were 3 x 4 cm in size. Sandpaper grit values used were 60, 80, 100, 120, 150, 180, 280, 320 and 400. Average particle sizes were 269, 201, 162, 125,100, 82, 52.2, 46.2, and 35 micrometres respectively. All sandpaper used adhered to ISO/FEPA (Federation of European Producers of Abrasives) standards.

Comparisons were presented in three Blocks according to level of difficulty- Easy, Medium and Hard as per pilot study (refer to example Set 1 in Appendix). Level of difficulty was determined by the percentage difference in average particle size (micrometres) for each pair. Easy comparison pairs ranged between 56% and 66% difference, Medium comparison pairs ranged between 28% and 42% difference and Hard comparison pairs ranged between 12% and 21% difference.

In each Block there were three *different* trials and three *same* trials (6 trials per block), making 18 trials in a complete set. A *same* trial was a trial in which the textures were identical in the pair comparison (e.g. 60 – 60), and a *different* trial was a trial in which the textures in the pair were different (60 – 80). Within each Block (level of difficulty) there was a different and same comparison for coarse, medium coarse and fine texture, (refer to Appendix). *Same* trials remained the identical across all blocks.

In each set the Blocks were presented in the same order – Easy, Medium and then Hard. Within each Block, same and different trials were randomised. Left - Right position in each trial was randomised in each block.

Design:

A mixed model design was used to examine group differences between typically developing individuals and individuals with ASD on task performance. The independent variables were participant group and level of difficulty. Level of difficulty operationally defined by *percentage difference in average particle size*. The dependent variable was *total proportion correct* for each level of difficulty.

Procedure:

The task was a forced-choice task to decide whether the two sheets were the same or different (as in the first pilot study). Prior to administering the experimental stimuli, 'test' stimuli were presented to the participant to ensure understanding of 'same-different'. Two of the 'test' stimuli consisted of simple black stickers presented on card. They were either the same (two dots) or different (one dot and one rectangle). Another two 'test' stimuli consisted of fabric squares that were either the same (two felt squares) or were different (one denim square and one sponge square).

Blocks were presented in the same order to each participant, but trials within each block were randomised across sets. Vision was occluded during presentation by presenting stimuli in a box. The opening of the box was covered with a curtain. Participants were required to use only their index finger or middle finger of their writing hand and move across the texture in a lateral motion indicated by the experimenter. Participants could take as long as needed to respond and could switch between sheets /patches as many times as needed to make a decision. If the participant appeared not to understand the task, then testing was discontinued.

Results

Typical sample age comparisons -

Participants were divided into three age groups. Scores for the typical sample were collated and are presented in Table 3.3. below.

Table 3.3. *Descriptive statistics for typical sample (N=28, standard error in brackets).*

Age Group	N	Mean CA	Total Proportion Correct
5 - 7	12	6.12 (.27)	.63 (.02)
8 - 9	8	8.13 (.13)	.67 (.03)
11 - 14	8	11.88 (.48)	.78 (.04)

A one-way Analysis of Variance (ANOVA) was conducted to explore any possible age differences in *total proportion correct*, and a significant effect of age was found, ($F(2,25) = 6.02$, $p = .007$). Post hoc tests revealed significant mean differences between group 1 and 3 ($p = .025$), but no significant difference between group 1 and 2 ($p = .782$), nor between group 3 and 2 ($p = .115$). Indicating that performance in the older group is significantly better than the youngest group.

Exploring possible differences in proportion correct across level of difficulty -

<u>Typical and ASD sample descriptives:</u>

Proportion correct for each level of difficulty was calculated for the typically developing and ASD group for comparison and are presented in the table below (standard error in brackets).

Table 3.4. *Proportion correct for each level of difficulty.*

Group	N	Easy	Medium	Hard
Typical	28	.75 (.168)	.65 (.141)	.64 (.137)
ASD	8	.56 (.153)	.60 (.214)	.50 (.167)

<u>Typical sample (N=28)</u> -

A repeated measures ANOVA was conducted to determine whether *proportion correct* is significantly different across levels of difficulty in the typical sample, and was found to be significant (*F(2,58)* = 6.56, *p* =.003), with the highest performance in the Easy level (M = .75), and lowest in the Hard level (M = .64). Pairwise comparisons revealed significant differences between the Easy and Medium level (*p* = .008), and the Easy and Hard level (*p* = .002), but not between the Medium and Hard level (*p* = .861). The effect size was large with a partial Eta squared of .302.

ASD sample (N=8) -

A repeated measures ANOVA was conducted to determine whether *proportion correct* is significantly different across levels of difficulty in the ASD sample, and no significant differences were found (*F(1,7)* = 1.53, *p* =.263, equal variance not assumed). The effect size was large with partial Eta squared of .203.

Matched sample comparisons -

For matched comparisons, five typically developing individuals and five individuals with ASD were matched on WISC raw scores. Summary scores are presented in Table 3.5 below.

Table 3.5. *Descriptive statistics for each participant group.*

Group	N	Mean CA (std)	Mean short-form WISC score (SE)	Total proportion correct Mean (SE)
Typical	5	6.60 (.547)	55.8 (5.90)	.64 (.05)
ASD	5	8.20 (.837)	56.4 (5.73)	.61 (.06)

No significant difference in raw WISC score was found between groups (*t*(8)= -.073, p =.944). An independent samples t-test was conducted to explore group differences in total proportion correct, and no significant differences were found (*t*(8) =.44, p =.67).

Pilot 2 conclusion

Results from the typically developing group show that the amount of discrepancy across levels of difficulty was still low, specifically between the Medium and Hard level of difficulty. For the ASD group performance was consistently poor across all levels. For Study 3 (below) the grit values 150 and 280 were removed. The Easy level was changed to the Medium level and the Medium to the Hard level. A completely new Easy level was created, with much greater percentage difference in average particle size in each trial comparison, to increase the likelihood of improved performance in the ASD group. In addition, typical matches for the ASD group are significantly younger in chronological age, so there is a need for an easier block of trials.

3.7 Study 3: *Tactile sensitivity in typical and atypical development*

Method

Participants:

Eighty-eight participants were recruited from schools in the North East of England. There were initially 21 ASD participants, but due to incomplete data sets, four had to be removed from analysis. There were 15 ADHD participants, but two left the school before testing was completed. Both the ASD and ADHD group consisted only of males, and the typical group had 23 males and 28 females. The remaining participant descriptives are presented in Table 3.6 below. Ethics for the study was approved by the local ethics committee at Newcastle University

Table 3.6. *Sample descriptives for each participant group (N = 88).*

Group	N	Age range (yrs)	Mean CA (yrs)
Typical	51	5 - 16	9.25
ASD	17	8 - 13	10.53
ADHD	13	8 - 13	11.15

The age range is greatest in the typical group, as would be expected to be able to match on general ability for further analysis to compare performance across groups (N = 13 for each group). The ASD and ADHD group were ability matched on the *short version* of the WISCIV assessment, which consists of two non - verbal and two verbal subscales (block design, picture concept, similarities, and vocabulary respectively).

Measures:

Social Communication Questionnaire (SCQ; ASD only)

The Social Communication Questionnaire (Rutter, Bailey & Lord, 2003) provides an easy and quick screening for autism spectrum disorders (ASD). The SCQ provides a measure of ASD symptomatology, with a cut-off score which can be used to indicate the likelihood that an individual has autism. This short questionnaire can be used from 4 years old. It is composed of 40 yes / no questions to be answered by the parent or primary caregiver. The authors recommend using a cut-off of 15 when differentiating ASD from non-ASD individuals. For the purposes of this study, the SCQ was used as an additional confirmation of ASD, in addition to an official diagnosis.

Strengths and Difficulties Questionnaire (SDQ; typical only)

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) is a short behavioural screening questionnaire for 3-16 year olds, that is completed by teacher or parent. The questionnaire is used by researchers, clinicians and in education. It consists of 25-items, on several different psychological attributes. It has five subscales, including Emotional symptoms, Conduct problems, Hyperactivity/inattention, Peer relationship problems, and Prosocial behaviour. It has been demonstrated to have good construct validity (Goodman, 1997), and predictive validity (Goodman, Renfrew & Mullick, 2000). For the purposes of this study, the SDQ was used to ensure that individuals in the control group did not have any undiagnosed behavioural difficulties.

Teacher Sensory Profile – The School Companion

The Teacher Sensory Profile (School Companion; Dunn, 2006) is a standardised assessment, used by teachers to assess the child's sensory processing behaviours in the classroom. It is used with 3 - 12 years old children. The data was summarised according to the four behavioural quadrants; Low Registration (Q1), Sensation Seeking (Q2), Sensory Sensitivity (Q3) and Sensation Avoiding (Q4; see previous chapter for descriptions of each quadrant).

WISC-IV short-form

The Wechsler Intelligence Scales for Children, version IV (WISC-IV; Wechsler, 2003) is a standardised battery of tests designed to assess both verbal and performance IQ. For the purposes of this study, two tasks designed to produce a non-verbal IQ measure, and two tasks designed to produce a verbal IQ measure were administered.

Non-verbal tasks – The Block Design task consisted of a series of red and white patterns that need to be copied using a specified number of small red and white blocks. Each item increases in difficulty level, with a maximum score of 68. Picture Concepts task is comprised of 28 items. The participant is asked to choose two / three pictures (increasing with difficulty) that are semantically related (e.g. sail boat and vehicle). The maximum score is 28.

Verbal tasks - The Similarities task is comprised of 23 items. The participant is asked to state how two items are related (e.g. blue and red are both colours). The Vocabulary task consists of 36 items, in which participants are asked to define words which increase in difficulty (for example ‘what is a bicycle’?). After five consecutive errors testing stops. A total verbal score was based on the sum of both tasks. For both tasks, some of the items can receive a score of 2 depending on detail given in the response. The total maximum scores are 44 and 68, for each task respectively.

For matching purposes, the non-verbal and verbal total scores were summed to create a *WISC raw score*. Total maximum score is 208 (sum of the four tasks).

Materials:

The sandpaper sheets were presented in pairs on card. Sheets were 3 x 4 cm in size. Sandpaper grit values used were 60, 80, 100, 120, 180, 320 and 400. Average particle sizes were 269, 201, 162, 125, 82, 46.2, and 35 micrometres respectively. All sandpaper used adhered to ISO/FEPA (Federation of European Producers of Abrasives) standards.

Comparisons were presented in three Blocks according to level of difficulty- Easy, Medium and Hard (refer to example stimuli in Appendix B). Level of difficulty was determined by the percentage difference in average particle size (micrometres) for each pair. Easy comparison pairs ranged between 113% and 129% difference, Medium comparison pairs ranged between 56% and 66% difference and Hard comparison pairs ranged 28% and 42%.

In each Block there were three different trials and three same trials (6 trials per block) repeated twice, making 36 trials in total. A same trial was a trial in which the textures were exactly the same in the pair comparison (e.g. 60 – 60), and a different trial was a trial in which the textures in the pair were different (60 – 80). *Same* trials were identical across all blocks. Very few participants completed two full sets, and therefore analysis was conducted on only one set - 18 trials.

Design:

A mixed model design was used for this study, with the within-subjects factor being the task (with three levels of difficulty) and the between-subjects factor being participant group (with three levels, typical, ASD and ADHD). The number of correct responses for ‘same’ and ‘different’ trials determined the dependent variable. This was calculated as HIT rates (correct responses on different trials), False Alarm rates (incorrect responses on same trials), and proportion correct which equals HITS plus *correct rejections* divided by *total number of responses.*

Procedure:

The task was a forced-choice task to decide whether the two sheets were the same or different. Prior to administering the experimental stimuli, 'test' stimuli were presented to the participant to ensure understanding of 'same-different' (in the case of young participants / participants with low level of understanding). Two of the 'test' stimuli consisted of simple black stickers presented on card. They were either the same (two dots) or different (one dot

and one rectangle). Another two 'test' stimuli consisted of fabric squares that were either the same (two felt squares) or were different (one denim square and one sponge square).

Blocks were presented in the same order to each participant, but trials within each block were randomised. Left - Right position of the texture in each trial was randomised. Vision was occluded during presentation by presenting stimuli in a box. The opening of the box was covered with a curtain. Participants were required to use only their index finger or middle finger of their writing hand and move across the texture in a lateral motion indicated by the experimenter. Participants could take as long as needed to respond and could switch between sheets as many times as needed to make a decision. The task lasted approximately 15 minutes.

Data Analysis:

Accuracy was coded as 1 for correct identification of whether the pair presented was the same or different, and 0 for incorrect responses. As a measure of sensitivity in discrimination *d'* was calculated by using the following equation: $d' = z(H)-z(F)$. Perfect accuracy was corrected for by converting proportion of 0 to $1/(2N)$, and proportions of 1 to $1-1/(2N)$, where N equals the number of trials the proportion is based, e.g. number of different trials in the Easy Block. Bias in discrimination was calculated using the following equation: $c = - [z(H) + z(F)]/2$.

Terms: ***d prime (d')*** *is a measure of sensitivity - a statistic that is used in signal detection theory. It provides a value of the separation between the signal (target) and the noise distribution (error) which is compared against the average (standard deviation) of the signal / noise distribution.*

Bias (c) *is a measure of the probability - the extent to which one response is more probable than another. The participant may be more likely to respond that a stimulus is present or more likely to respond that a stimulus is not present.*

All data was checked for normality before analysis carried out.

Results

Exploring age differences in the Typical sample -

Participants were divided into three age groups. Scores for the typical sample were collated and are presented in Table 3.7 below.

Table 3.7. *Descriptive statistics for typical sample (N =51).*

Age group (years)	N	Mean CA (standard deviation)	Mean short-form WISC score (standard error)	Total proportion correct Mean (standard error)
5-7	13	5.23 (1.24)	48.85 (7.018)	.68 (.026)
8-11	25	8.88 (.67)	97.32 (3.83)	.83 (.012)
12-16	13	13.92 (1.55)	128.46 (9.29)	.84 (.013)

A one-way Analysis of Variance (ANOVA) was conducted to explore any possible age differences in *total proportion correct (p(c))*, and a significant effect of age was found ($F(2, 50) = 23.34$, $p < .001$). Post hoc tests revealed significant mean differences between group 1 (M=.68) and 2 (M=.83; $p < .001$), and group 1 and 3 (M= .84; $p < .001$), but no significant difference was found between groups 2 and 3 ($p = .890$). Indicating that performance in the youngest group is significantly worse than the two older groups.

An independent t-test found no significant gender differences in *total proportion correct* ($t(49)=1.48$, $p = .12$, equal variance not assumed).

Exploring differences in proportion correct for levels of difficulty in the Typical sample (N = 51)

A repeated measures ANOVA was conducted to determine whether proportion correct is significantly different across levels of difficulty in the task as depicted in Figure 3.1 below, and was found to be significant ($F(2,100) = 117.60$, $p < .001$). Highest level of accuracy was found in the EASY level (M=.95) and lowest in the HARD level (M =.64). This indicates that level of task difficulty affects accuracy in discrimination across same and different comparisons as measured by proportion correct for each level of difficulty.

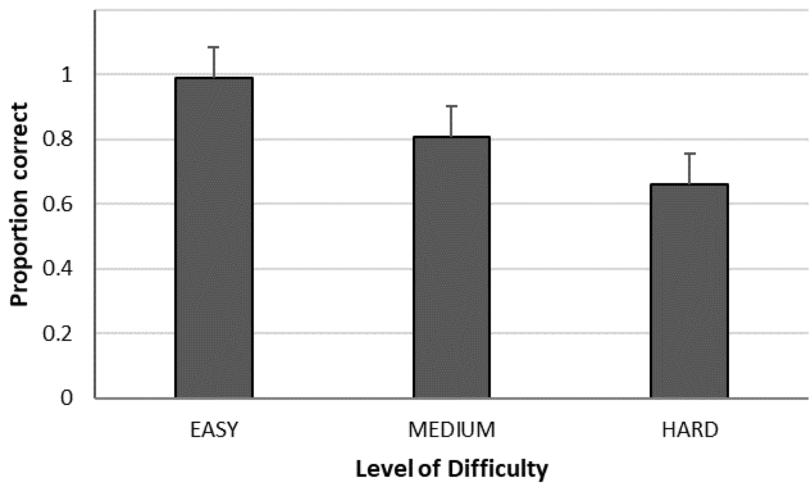


Figure 3.1. *Proportion correct across levels of difficulty. Error bars represent standard error.*

Differences in HIT rate for levels of difficulty in typical sample–

Calculating the HIT rate gives a more accurate measure of discrimination. Taking into consideration false alarm rate we are able to calculate a more accurate measure of discrimination sensitivity (*d')*.

A Repeated Measures ANOVA revealed that performance, as measured by HIT rate in Figure 3.2 below was found to be significant across the three levels of difficulty ($F(2,100) = 59.76$, $p < .001$), with highest HIT rate in the Easy level (M=.89) and lowest HIT rate in the Hard level (M=.52), indicating that level of difficulty is related to discrimination of ‘different’ texture comparisons.

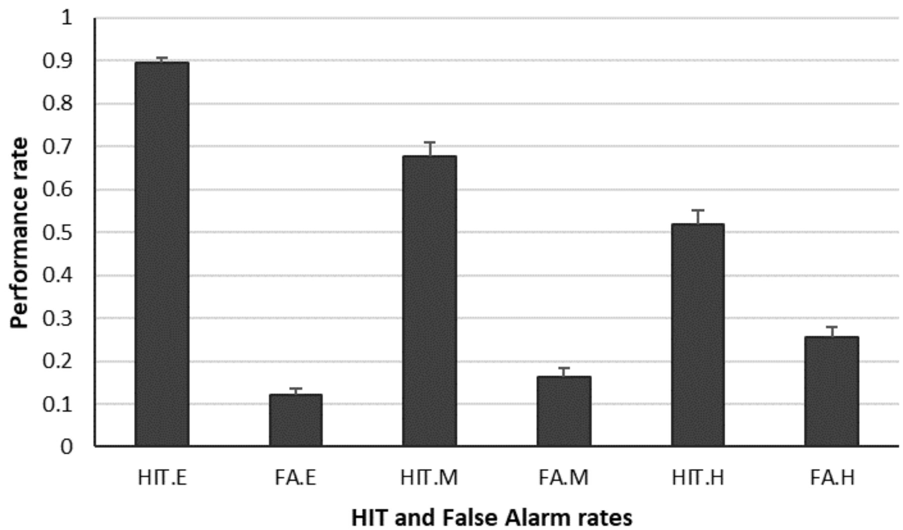


Figure 3.2. *HIT rates and False Alarm rates for each level of difficulty (E, M, H). Error bars represent standard error.*

One-sample t-tests were conducted on the HIT rate for each level of difficulty to determine whether the HIT rate was significantly different to chance (50%). The HIT rate for Easy and Medium level were found to be significantly above chance (p <.001) and the HIT rate for the Hard level was found not to be significantly different to chance (t(50) = .519, p = .606).

Sensitivity measure (d') -

A further ANOVA was carried out to determine whether discrimination sensitivity (*d'*) was significantly different across the levels of task difficulty. Level of difficulty was found to be significant (F(2,100) =188.44, p <.001) with the least sensitivity found for the HARD level (*d'* = .79) and most sensitivity in the EASY level (*d'* = 2.55).

Response bias measure (c) –

ANOVA was carried to explore response bias (c) across level of difficulty, and was found to be significant (F(2,100) = 17.41, p <.001), with response bias in Easy level (c = -.032) in the Medium level (c = .256) and in the Hard level (c = .354). There were low bias levels across all conditions.

Exploring differences in performance in matched samples -

Typical, ASD and ADHD matched samples:

For group comparisons, typical, ASD and ADHD participants were matched on WISC raw scores. Summary scores are presented in Table 3.8 below.

Table 3.8. *Descriptive statistics for each participant group*

Group	N	Age Mean (standard deviation)	Mean short-form WISC score (standard error)	Total proportion correct Mean (standard error)
Typical	13	8.78 (2.28)	85.23 (8.35)	.81 (.01)
ASD	13	11.00 (2.71)	82.85 (5.68)	.78 (.02)
ADHD	13	11.15 (1.34)	85.46 (8.34)	.75 (.02)

There was no significant difference in WISC raw score across groups ($F(2,36) = .037$, $p = .964$). Post hoc tests using Dunnett T3 found no significant differences between Typical (M = 85.23) and ASD (M = 82.85; $p = .99$), Typical and ADHD (M= 85.46; $p = 1.00$) or between ASD and ADHD ($p = .99$).

Differences in proportion correct –

A 3 x 3 mixed model ANOVA was conducted to explore group differences in proportion correct for each level of task difficulty as depicted in Figure 3.3 below. A main effect of *difficulty* was found ($F(2,72) = 100.54$, $p < .001$). Most accurate performance in the Easy level and least accurate in the Hard level. No main effect of group was found ($F(2,36) = 2.17$, $p = .129$) and no significant interaction was found for group and level of difficulty ($F(4,72) = 1.38$, $p = .251$).

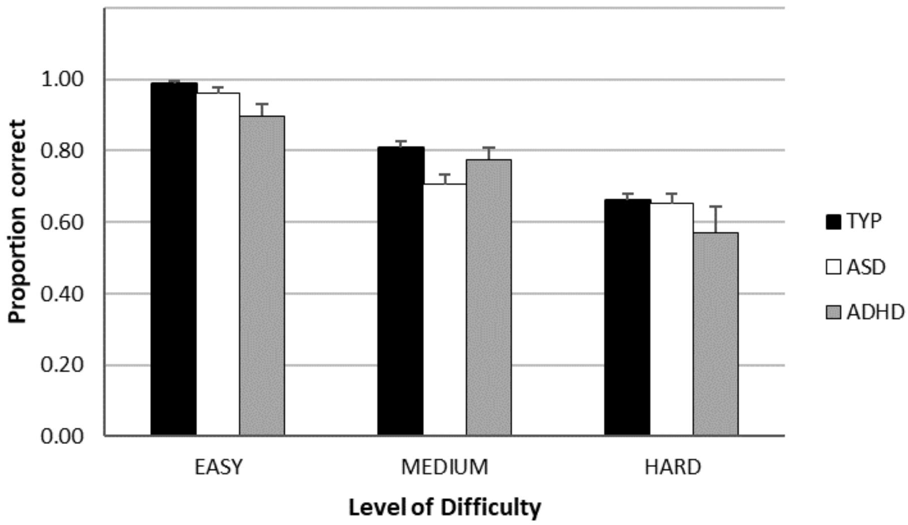


Figure 3.3. *Proportion correct for each level of difficulty across participant groups. Error bars represent standard error.*

Differences in HIT rate -

A mixed model ANOVA was conducted to explore group differences in Hit rate for each level of difficulty, depicted in Figure 3.4 below. A significant main effect of difficulty was found (F(2,72) = 121.75, p < .001), with the highest *overall HIT rate* in the Easy level (M = .91) and the lowest *overall HIT rate* in the Hard level (M = .41). No main effect of group was found on *overall HIT rate* (F(2,36) = 1.96, p = .155). A significant interaction was found for HIT rate across *each* level of difficulty and group (F(4,72) = 2.94, p < .05) and is depicted in figure 3.5 below. Post-hoc comparisons revealed a significant group difference in the Hard level (p =.04), but no significant group difference in the Easy level (p = .213), nor Medium level (p = .199).

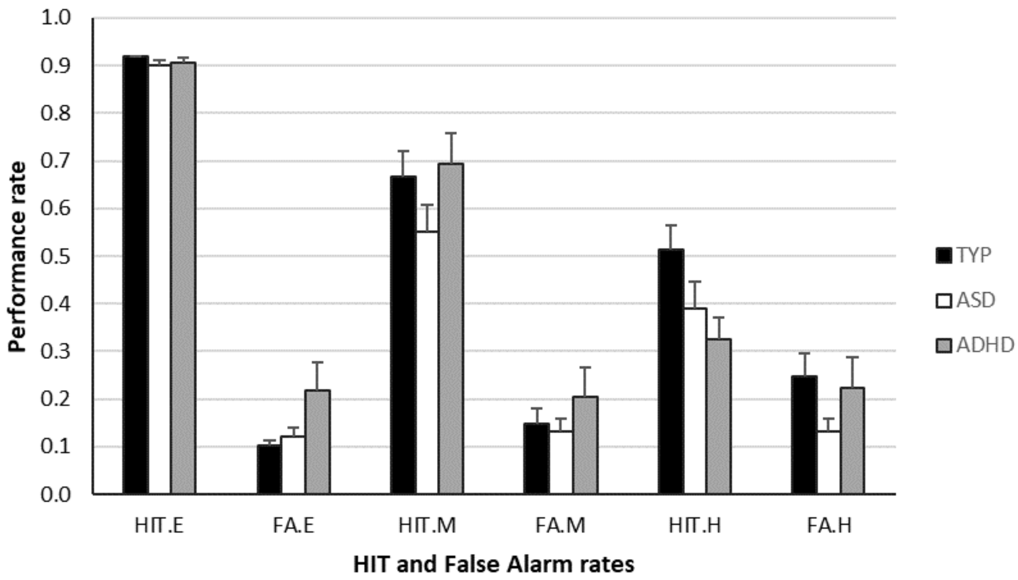


Figure 3.4. *HIT rates and False Alarm rates for each level of difficulty (E, M, H) across groups. Error bars represent standard deviation from mean.*

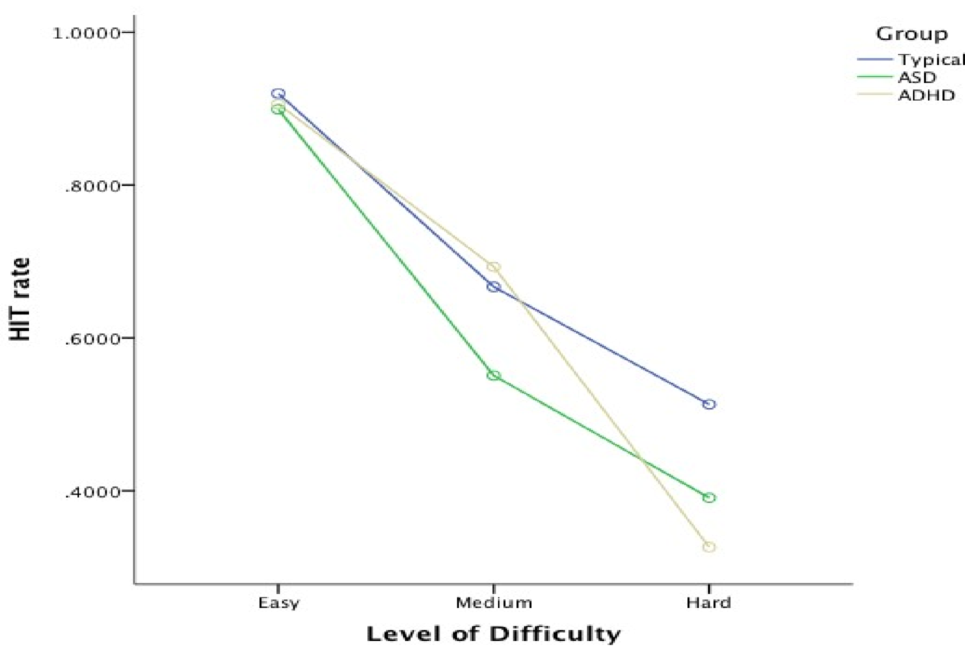


Figure 3.5. *HIT rate across level of difficulty for each participant group.*

Sensitivity measure (d') -

A further mixed model ANOVA was carried out to determine whether discrimination sensitivity *(d')* was significantly different between groups for each level of task difficulty. A main effect of level of difficulty was found ($F(2,72) = 101.36$, $p < .001$), with least sensitivity in the Hard level ($d' = .11$), and most sensitivity in Easy level ($d' = 2.49$). No main effect of group was found ($F(2,36) = 2.05$, $p = .143$), indicating that *overall* sensitivity is the same across participant groups. No significant interaction was found between group and sensitivity for each level of task difficulty ($F(4,72) = 1.39$, $p = .245$).

Response bias measure (c) -

ANOVA was carried out to explore response bias between groups across level of difficulty. A main effect of level of difficulty was found ($F(2,72) = 60.59$, $p <.001$), with increasing response bias from lowest in the Easy level (c = -.101), to higher in the Medium level ($c = .331$) and highest in the Hard level ($c = .610$). No main effect of group was found ($F(2,36) = 1.63$, $p = .209$). A significant interaction was found between group and response bias for level of difficulty ($F(4,72) = 3.45$, $p <.05$). Post hoc analysis on response bias for HARD level revealed no significant differences in response bias across groups. Small group size may account for result. Sample small to really explore the interaction, however ADHD group appear to increase in bias more than the typical and ASD group in Hard level.

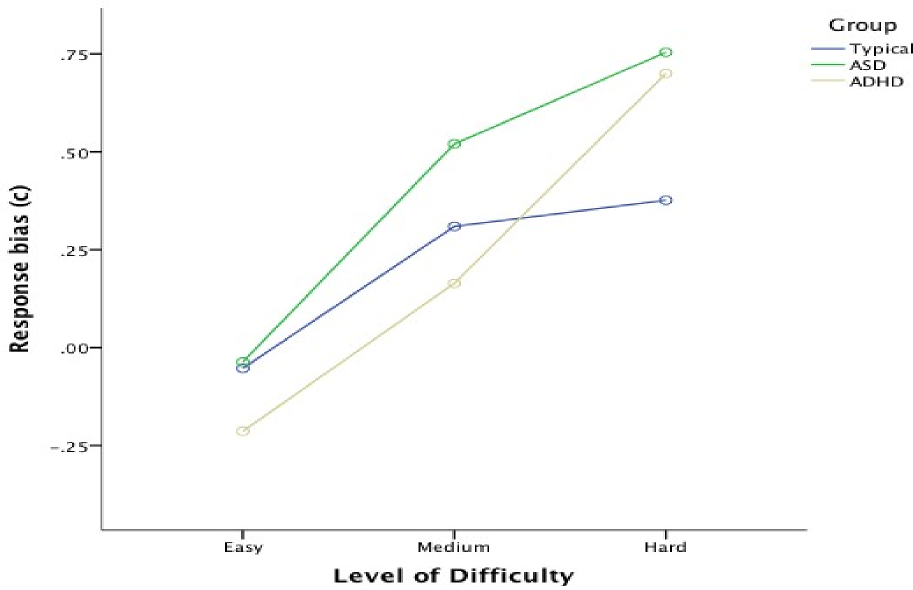


Figure 3.6. *Response bias across level of difficulty for each participant group.*

Sensory Profile summary for atypical comparison groups

Summary scores for the Teacher Sensory Profile are presented below for each atypical comparison group. Included in Table 3.9 is the average total proportion correct for the tactile discrimination task. Of the total sample of ASD individuals, only 14 Sensory Profiles were completed.

Table 3.9. *Sensory Profile four quadrant summary and total proportion correct.*

	Low Registration	Sensory Seeking	Sensitivity	Avoiding	Total Proportion Correct
ASD (N= 14)					
Mean	53.07	39.36	47.50	54.29	.78
Std Dev	(10.80)	(11.67)	(11.0)	(13.47)	(.068)
ADHD (N=13)					
Mean	56.85	39.08	53.23	62.85	.75
Std Dev	(13.93)	(10.70)	(13.30)	(11.90)	(.077)

Exploring Sensory Profile group differences

A between-subjects MANOVA was conducted to explore group differences across the four sensory quadrants. No group difference was found for any of the four quadrants; Low registration ($F(1,25) = .624$, $p = .44$), Sensory Seeking ($F(1,25) = .004$, $p = .95$), Sensitivity ($F(1,25) = 1.50$, p

= .23) and Avoiding ($F(1,25) = 3.04$, $p = .09$). The ASD and ADHD group do not significantly differ in their sensory profiles.

Sensory Profile and Texture Discrimination

The relationship between the four quadrants and texture discrimination were explored for each group separately using Total Proportion Correct as a measure of discrimination accuracy.

ASD (N= 14)

In the ASD sample, no significant correlations were found between Total Proportion Correct and any of the four sensory quadrants; Low Registration ($r(12)= -.361$, $p = .20$), Sensory Seeking ($r(12) = -.155$, $p = .60$), Sensitivity ($r(12) = -.156$, $p = .59$), and Avoiding ($r(12) = -.180$, $p = .54$).

ADHD (N=13)

In the ADHD sample no significant correlations were found between Total Proportion Correct and any of the four sensory quadrants; Low Registration ($r(11)= .036$, $p = .91$), Sensory Seeking ($r(11)= -.454$, $p = .12$), Sensitivity ($r(11) = -.170$, $p = .58$), and Avoiding ($r(11) = -.077$, $p = .80$).

3.8 Discussion

The aim of the study was to explore tactile sensitivity by exploring accuracy on a fine texture discrimination task. It was predicted that individuals with ASD and individuals with ADHD would be more accurate at discriminating fine texture than typically developing individuals. Contrary to these predictions no group differences were found, with all groups performing at the same level of accuracy. None of the groups performed at chance for the Easy and Medium level, indicating all groups were able to do the task. Study 3 results showed that all groups perform equally well on *proportion correct* across the three levels of difficulty, with the most accurate performance in the Easy level, and lowest performance in the Hard level. When considering only the HIT rate, a significant interaction was found between level of task difficulty and group, but no significant interaction was found when using *d prime*, which suggests that there are group differences in false alarm rate across levels of difficulty. This is supported by the significant interaction between group and difficulty level on the bias measure (c). This suggests that there are differences in bias between participant groups on certain levels of difficulty. However, in order to accurately interpret this significant interaction, further analysis will need to be carried out taking into account chance level accuracy. When considering HIT rate performance is below chance level in the HARD condition for the ASD and ADHD group, therefore the interaction cannot be meaningfully interpreted.

A limitation to the design is the low number of trials in each block. In addition, correcting for perfect scores may have resulted in further narrowing the possible range of scores, i.e. minimising any difference between high and low average scores, by doing so reducing statistical power (increasing chance of type II error). However, given the ability of individuals in the atypical sample, trial numbers had to be kept low.

A possible reason for the non-significant finding is the use of very fine texture. Gliner (1967) examined tactual discrimination thresholds of shape and texture in young children. By presenting pairs of shapes and texture patches in a same/different task to two groups of children (5-year-olds and 8-year-olds), results revealed an increase in texture sensitivity with age, but not to shape. Findings also showed that rougher textures were easier to discriminate in both age groups. Perhaps focussing on fine texture was too difficult for children, including those diagnosed with ASD, and ADHD. Consistent with our study results of a significant positive correlation with age and proportion correct in the younger age group (5 -7 years old), Gliner (1967) found increased sensitivity with age (between 5 years and 8 years old).

Although participants were asked to use their index finger in a lateral motion when haptically exploring the texture, a possible limitation may be that there was no control for exposure time on each stimulus, neither control for speed of movement or tactile force. Although, given the type of sample in this study, more precise control of hand movement would have been extremely difficult as in other studies of roughness perception (e.g. Lederman, 1974). Despite this limitation, some studies have shown that if participants used fingers or their palm, no difference was found in overall discrimination (e.g. Craig & Lyle, 2001). Heller (1989) also stated that whether lateral motion or other exploratory procedures were used, it would not fundamentally change perception. In support of Taylor and Lederman’s (1975) model of tactual roughness perception mentioned in the Introduction, Lederman (1983) demonstrated that tactual roughness perception, i.e. magnitude estimates of felt roughness, of linear gratings were not affected by either spatial period or to the difference between groove and ridge. Lederman also noted that there were negligible effects on perceived roughness when varying the relative speed of motion between skin and surface, regardless of whether active or passive touch was used. Lederman argued against a temporal coding theory of roughness perception, i.e. argued that the dynamic aspects of the signal (e.g. the rate of skin displacement) were not a necessary component to the perception of roughness. Therefore, it is unlikely that the type of movement, or speed of movement would have affected texture discrimination in this study. With regards to texture gradient differences, even after adjusting level of difficulty based on results from two pilot studies, the hard level was still too difficult (performance at chance). There are contradictory results regarding detectable difference in fine texture discrimination, with some research suggesting fine texture discriminative ability in adults with small difference in particle size (3 micro millimetres) and other research shows discrimination only possible at about 25 micro millimetres difference (e.g. Hollins, Bensmaia, Karlof & Young, 2000; Bensmaia & Hollins, 2003). Therefore, perhaps the task design was not sensitive enough to detect group differences from the study sample.

The findings show that despite reported sensory symptoms on the Sensory Profile, they do not display such abnormalities on the task performance e.g. tactile defensiveness / unusual tactile functioning reported and are able to actively explore all textures without displaying aversion or withdrawal. Therefore, perhaps the tasks are either not sensitive to or not related to the specific symptoms usually displayed by the individual. According to Baranek and Berkson (1994) tactile defensiveness is also associated with over-sensitivity and slower habituation rates to repeated tactile stimulation, which would suggest heightened sensitivity to tactile stimulation. However, we cannot be sure our sample of ASD individuals were tactile defensive. Royeen and Lane (1991) describe the distinction between tactile defensiveness and tactile discrimination as being separate deficits. Since no group difference was found in discriminatory ability it may be that the individuals within this sample, despite having clearly different sensory profiles to the typically developing individuals, show no deficit in tactile discrimination. In support of this proposal, Case-Smith (1991) found a low correlation between tactile defensiveness and tactile discrimination and concluded that they are two separate, but related aspects of tactile functioning.

Research study findings are inconsistent on hypersensitivity in autism, which may be due to differences in methodology. No reported differences in tactile thresholds between ASD and controls have been found when examining tactile thresholds on the forearm and palm to light touch, whereas significant differences in tactile threshold were found when examining vibrotactile frequency sensitivity (Cascio et al. 2008). In addition, Robertson and Baron-Cohen

(2017) suggest that perhaps enhanced / heightened sensitivity may be specific to certain types of stimulation in all modalities, such as high frequency sound and high frequency vibrotactile stimulation. Therefore, perhaps no enhanced sensitivity was found due to the wrong task choice, i.e. not specifically examining discrimination of high frequency vibrotactile stimulation.

There is a lack of evidence to support a difference in baseline sensory performance measured by sensory thresholds, between ASD and matched controls (Bertone et al. 2005, Khalfa et al. 2004) which may suggest that individuals with ASD are not more sensitive to sensory stimuli per se, but may process that information differently, which could result in observed unusual reactions to sensory stimulation.

The results of these studies cannot support the prediction of heightened sensitivity in autism or hyper-responsivity in ADHD in the tactile modality. No difference in texture discrimination

ability was found between typical, ASD and ADHD group. It can be concluded that perhaps; 1) the reported over-responsivity to texture is not due to a perceptual difference but may be an affective reaction or 2) perhaps the unusual sensory response to tactile stimuli is caused by a

difficulty integrating visual and tactile information. Research suggests a difficulty integrating sensory information in individuals with autism (Iarocci & McDonald, 2006). In the following chapter, experiments will explore visual -tactual matching of texture in typical and atypical development.

Chapter Four

Cross-Modal Matching of Texture

4.1 Introduction

The main aim of this thesis is to explore unusual tactile processing in atypical development. The experiments conducted thus far have indicated that texture preferences are similar for typical and atypical development, despite anecdotal reports suggesting otherwise. In addition, fine texture discrimination was explored in Chapter 3, with the prediction that individuals likely to have tactile defensiveness would be more accurate at discrimination than typically developing individuals but no group differences were found between typically developing individuals and those with ASD and ADHD. This experimental chapter explores the possibility that reported unusual tactile response observed in individuals with autism and ADHD may be due to difficulty transferring visual-tactual information between modalities. The following series of studies explore visual – tactual matching of fine texture, matching of everyday textures and matching of texture & shape.

4.1.1 *Cross - modal transfer in typical development*

The recognition of identity or similarity between information gained by different modalities has been referred to as cross-modal transfer or intersensory equivalence, e.g. the mapping of what is seen to what is felt. Interest in the ability to transfer information across modalities has a long history dating back to Berkeley (1709) and Locke (1690/1975) with the research focusing primarily on cross modal ability in typically developing individuals. Cross-modal transfer in typical development has shown that young infants are successfully able to perceive visual information, that has been acquired from the tactile modality and visa versa (e.g. Meltzoff & Borton 1979; Rose, Gottried & Bridger, 1981). As infants are successfully able to transfer information across modalities with ease, it has been debated whether this process of integration is innate or learnt (Spence & Deroy, 2012). Since this capability is present from early development, it has been suggested that cross-modal abilities are crucial for cognitive functioning (Birch &

Belmont, 1965; Ettinger, 1961). Research has found a positive correlation between visual-tactual transfer and later mental age and IQ (e.g. Rose & Wallace, 1985; Rose & Feldman, 1995).

The majority of the research with typically developing infants, children and adults has focussed specifically on visual-haptic matching of shape, visual-haptic roughness discrimination, and roughness equivalence across modalities (e.g. Picard, 2006; Tiest & Kappers, 2006). The literature on cross-modal transfer of shape has shown that infants and young children are able to successfully transfer visual-haptic shape information (e.g. Bushnell and Baxt, 1999).
There is evidence for cross-modal transfer of shape in children as young as 6-months-old (Rose, Gottfield & Bridge, 1981a) and 12-months-old (Rose, Gottfield & Bridge, 1981b). There has been less research however, on cross-modal transfer of texture and of combining texture and shape in cross-modal tasks.

4.1.2 *Cross - modal studies involving texture*

Some studies have included texture in cross modal tasks, and others have mainly considered roughness perception. This has been the most intensively studied area and focussed on roughness discrimination using metal gratings (Lederman, 1981; 1983) and sandpaper (Heller, 1982; Jones & O'Neil, 1985). Meltzoff and Borton (1979) were one of the first to explore visual-tactile transfer of texture using oral exploration. Infants were given either a smooth pacifier or lumpy pacifier to suck. When presented with a visual display of both, they reliably looked longer at the corresponding pacifier. The authors concluded that the infants were able to successfully transfer texture information from the oral sensation (of the pacifier) to the correct visual representation. A more recent study by Molina and Jouen (2003) investigated neonates' (4-weeks old) ability to haptically compare objects that varied in texture density. In this study objects were held simultaneously, one in each hand. Holding time and hand-pressure frequency were measured. Results showed that in the non-matching condition hand pressure significantly differed between the left and right hand, indicating that neonates were able to compare varying texture densities, demonstrating very early capacity for intermodal exploration of texture.

Combining shape and texture, Sann and Streri (2007) investigated cross-modal transfer in human newborns in a series of experiemnts. In an intersensory procedure, newborn infants were habituated to either a visual or tactual target, then presented with a novel or familiar visual or tactual target (depending on the direction of transfer). Results showed that performance was not bi-directional for shape (the transfer of shape information was from touch to vision only), but newborns were successfully able to transfer texture information bi-directionally. The authors concluded that we extract information differently for vision and touch for different object properties and emphasised that the property of texture is amodal. Therefore, different object properties have different salience during haptic exploration, i.e. have material properties such as texture and compliance, and geometrical properties such as size and shape (Klatzy & Lederman, 1993).

4.1.3 *Cross-modal transfer in atypical development*

There has been research into cross-modal matching in atypical development, but the results are conflicting, and studies limited. For example, one of the earliest studies by Hermelin and O'Connor (1964) explored cross modal transfer of shape between typically developing children and children with autism and reported no significant differences in visual-tactual matching. Contrary to this, Smith and Tunick (1969) examined cross-modal transfer in individuals who were lower functioning (referred to as 'retarded' in this dated literature). In the study, the objects used for discrimination were plastic geometric forms (e.g. cone, sphere, cube, cylinder) and textures, which included smooth, foam, rubber and rough sandpaper. Results found that only when the same cue was given in both the visual and tactual trials, were participants able to successfully solve the matching problems. In all other scenarios, no cross-modal transfer was observed.

In a more recent study, Nakano, Kato and Kitazawa (2011) reported better visual-tactual transfer of shape for individuals with autism compared to controls. The task involved placing foam shapes on to a board with the matching cut-out shapes, in visual only, tactile only and cross-modal conditions. Individuals with autism were more accurate at matching the visual shape to the tactile board of missing cut-out shapes, than the TD control group.

Current research into cross modal transfer in autism has focussed on auditory-visual judgements of affective congruence (Loveland, Steinberg, Pearson, Mansour & Reddoch, 2008), and emotional expression (Matsuda & Yamamoto, 2015), with results showing that individuals with autism perform equally well as typically developing individuals at intramodal matching but are less accurate at cross-modal matching. For example, Matsuda and Yamamoto (2015) explored intramodal and cross-modal transfer of emotional expression in children with and without autism. The intramodal task was to match pictures of facial expressions depicting the same emotion. The cross-modal task involved listening to an affective prosody (i.e. the word ‘sensei’) representing one of four emotions (happy, surprised, angry or sad), and matching this auditory prosody with a picture depicting the same emotional expression. The results showed that children with autism were equally accurate at intramodal matching as TD children but were less accurate than the TD children in cross-modal matching of emotional expression. More recently fMRI has been used to explore brain activation during audio-visual integration and found that TD adolescents show significantly more brain activation than individuals with autism while performing an emotional congruence task (Loveland, Steinberg, Pearson, Mansour & Reddoch, 2008). This finding, in conjunction with studies showing poorer performance in cross-modal matching in autism, may support a neurological explanation for this difference in performance. However, other research claims that the ability to integrate visual-auditory information is unimpaired in individuals with autism, challenging study findings (e.g. Keane, Rosenthal, Chun and Shams, 2010; de Boer-Schellekens, Keetels, Eussen & Vroomen, 2013).

In addition, individuals with autism have been found not to display the bouba - kiki effect (Oberman & Ramachandran, 2008). The bouba - kiki effect is the finding that cross-modal correspondences are found between non-sense words and visual images. During the task, participants are required to pair nonsense shapes with nonsense words. Results showed that 88% of the time, typical children chose the correct nonsense word, whose phonemic structure corresponded to the visual shape of the stimuli. In comparison, children with autism, only correctly matched the nonsense word and shape 56% of the time. Köhler (1929) first reported this finding but has been replicated more recently (Ramachandran & Hubbard, 2001, 2003). Cross-modal ability to combine sensory information across modalities seems to be present from early development, even when there seems to be no logical meaningful connection. There is evidence for such cross-modal correspondence in 20-30 day-old-infants (Lewkowicz & Turkewitz, 1980). Yet, the evidence mentioned above would suggest that perhaps this ability may be delayed or impaired in individuals with autism. This could explain why individuals with autism be less accurate in matching visual-haptic texture information.

Aims

As previously discussed in this thesis certain textures are reported to cause aversive reactions to individuals diagnosed with autism. It is also known that individuals with autism may be fascinated by certain textures. The studies summarised in Chapters 2, and 3 found no perceptual differences between typically developing individuals and those with autism in either texture preference, tactile sensitivity or preference for complexity. Given that individuals with autism have difficulty processing sensory information (e.g. Tomchek & Dunn, 2007), perhaps the unusual reaction to texture observed in individuals with ASD is due to a difficulty integrating tactile and visual information of texture.

The following studies aim to explore whether individuals with ASD have difficulty with 1) visual-haptic matching of fine texture, 2) visual-tactile matching of everyday texture, 3) visual-haptic matching of global shape and texture, and 4) visual-tactile matching of texture in a meaningful context. It is predicted that individuals with autism would be less accurate than matched typically developing controls at matching textures cross-modally, i.e. with fine texture, everyday textures and textured shapes. A difficulty with cross-modal transfer may help to explain why certain textures cause aversive reactions to some individuals with autism, if there is a mismatch of expectation of what things feel like compared to what they see. Individuals with ADHD are expected to be less accurate with cross-modal matching but not to the same degree as individuals with autism. Literature presents evidence for sensory processing difficulties in ADHD (Dunn & Bennett, 2002), which could affect performance in a cross-modal matching task. This additional clinical group was also included in the later studies in this chapter to determine whether any difficulties with cross-modal matching observed in the autistic group are unique to that developmental disorder (therefore testing syndrome-specificity). There are no other studies to my knowledge that have explored accuracy in cross-modal transfer of everyday textures and textured shapes in autism.

4.2 Study 4: Visual-tactile matching of fine texture

Study 4 was designed to explore cross-modal matching of everyday fine textures, i.e. textures that individuals are most likely to encounter daily. These textures included those mentioned in anecdotal reports to cause aversive responses or fascination in individuals with autism. These textures were also included in the Texture Preferences and Aversion Questionnaire (i.e. fine and coarse sandpaper).

Method

Participants:

Fifty-one typically developing children, 34 females and 17 males (Mean age = 8.31, age range 5 to 16 years old) and 17 children diagnosed with ASD, 3 females and 14 males (Mean age = 11.00, age range 7 to 16 years) participated in the study. All children were recruited through schools in the North East of England. Ethics for the study was approved by the local ethics committee at Newcastle University. All children in the ASD group had previously received a clinical diagnosis of autism by experienced clinicians using the guidelines of standard criteria (DSM-IV; American Psychiatric Association, 1994).

Measures:

The same measures as the previous study were used, which included; short form WISC-IV, the Social Communication Questionnaire (ASD only), and the Strengths and Difficulties Questionnaire (typical only). These additional measures were used as an extra measure for diagnosis and to ensure typically developing individuals did not have undiagnosed disorders. Details of the questionnaires can be found in Chapter 2. The previous study used the Sensory Profile School Companion (for ease of use with that particular sample), but in the follow-up study the Sensory Profile Short Form was used (details below).

<u>Sensory Profile Short Form (Dunn, 2006)</u>

The Sensory Profile Short Form (Dunn, 2006) is a judgment-based questionnaire for 3 – 14 years old children which can be completed by the parent (caregiver) / teacher. Used to identify patterns of responses and the effects of sensory processing on the child’s functioning at home / school environment. Since no relationship was found in previous studies presented in this thesis, the short version was used only as a control. The questionnaire consists of 7 subscales, measuring sensory processing across all sensory modalities, with a total of 38 items (maximum score 190). The Cronbach’s Alpha for internal consistency between subscales ranges from .47 to .91 (Dunn, 1999).

Materials:

Visual panel:

A row of eight sandpaper cards were presented on a long cardboard panel, measuring 65cm x 15cm. The cards of sandpaper were 8cm x 9cm. The sandpaper cards were arranged in order from coarse to fine texture. The sandpaper grit values used were as follows; 60, 80, 100, 120, 180, 220, 320 and 400. The sandpaper panel was turned around to alternate the direction of roughness across trial blocks. Below each sandpaper card was a number corresponding to the position of the card, i.e. Numbers 1 to 8. Numbers were necessary for the participant to be able to choose a visual card without touching the texture. The numbers were stuck to a transparent plastic strip, which was removeable to accommodate change in direction (figure 4.1 below).

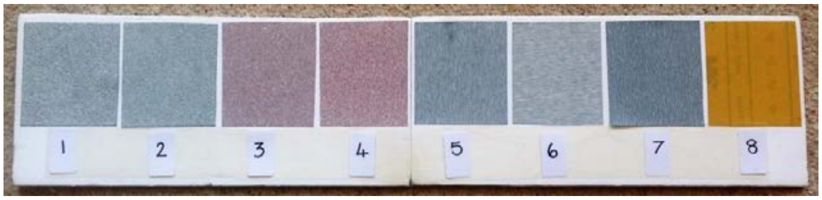


Figure 4.1: *Visual panel of sandpaper squares arranged from coarse to fine*.

Tactile cards:

The tactile stimuli consisted of four sandpaper cards measuring 8cm x 9cm. The four sandpaper grit values used were 100, 120, 180, and 220. These four are the central sandpaper grits from the visual panel. These were chosen to allow for observable shift in response. Each stimulus was presented twice in each block; eight trials were presented with the visual panel *coarse to fine*, and eight trials when the panel was *fine to coarse*, (a total of 16 trials).

Design:

A between-subjects design was used for this study, exploring differences between typically developing individuals and those with ASD. The *average distance* away from the target stimulus was one dependent variable. *Direction of shift*, measured as negative or positive average distance from the target, was the second dependent variable.

Procedure:

The trials were presented in two separate blocks to control for direction of roughness. Block 1 consisted of the visual panel presented *coarse to fine* (grit 60 - 400). In Block 2, the visual panel was presented *fine to coarse* (grit 400 - 60). The visual panel remained in view throughout all trials. There were eight trials in each block, making a total of 16 trials.

In each trial, a sandpaper card was presented to the participant inside a box to occlude vision. Each card was dragged three times, at the rate of 1 stroke per second, beneath the participants index finger (of their writing hand). The participant was asked to choose the visual card (from the panel) that was the same as the one they could feel. After 8 trials (Block 1), the visual panel was reversed, and the remaining 8 trials completed (Block 2). All trials were randomly presented within each block.

Data Analysis:

The average distance was calculated by taking the target number away from the individual's response number. For example, if the tactile card presented to the individual was number 3, and they choose 2 from the visual card, then the distance away from target would be recorded as 1 (ignoring the sign of the number). A higher value would indicate less accurate visual - tactile matching. Direction of shift from the target stimulus was calculated by averaging the distance from the target across trials, retaining the sign (- / +). A positive average would indicate a bias in response towards finer texture, whereas a negative average would indicate a bias in response towards coarser texture.

All data was checked for normality before analysis carried out.

Results

Average Distance

Overall sample decsriptives

The initial variable of interest was the *average distance* from the target stimulus. Summary data for the entire sample, split by group, are presented in the table below (standard deviation in brackets).

Table 4.1: Sample descriptives including *average distance from target (standard deviation in brackets).*

	N	Mean CA	Mean WISC raw score	Average distance
TYP	51	8.31 (3.13)	64.94 (31.67)	1.39 (.43)
ASD	17	11.00 (3.06)	97.29 (39.25)	1.56 (.53)

Age group difference in average distance from target was then explored for each group separately. The age group split was different to the previous studies as there were substantially more 5 to 6-year-old children. Data summary for each age group is presented below in Table 2.

Table 4.2: Age group descriptives for each sample including *average distance from target (standard deviation in brackets).*

	Age Group	N	Mean CA	Mean WISC raw score	Average Distance
TYP	*5-6 years*	21	5.63 (.498)	46.67 (14.50)	1.40 (.40)
	7-9 years	15	8.00 (.845)	55.87 (15.19)	1.63 (.43)
	10-16 years	15	12.40 (2.23)	99.60 (34.26)	1.13 (.33)
ASD	*7-9 years*	6	7.50 (.548)	64.00 (31.12)	1.86 (.59)
	10-16 years	11	12.91 (.563)	115.45 (30.87)	1.39 (.43)

Age group differences in the typical sample –

A one-way Analysis of Variance (ANOVA) was conducted to explore any possible age differences in *average distance* from the target, and a significant effect of age was found ($F(2,48) = 6.12$, $p = .004$). Post hoc tests using Dunnett T3 revealed significant mean differences between group 2 (7-9 years; M=1.63) and group 3 (10-16 years; M= 1.13; $p = .005$), but no significant difference was found between group 3 and 1 (5-6 years; M=1.40; $p = .103$), nor between groups 2 and 1 ($p = .291$). Indicating that performance in the 7- 9 year-old group is significantly less accurate than the older group (10 -16 year-old), but there is no significant difference between the two youngest groups.

An independent t-test revealed no age group difference in *average distance*, between 7-9 year-old and 10-16 year-old children with ASD, $t(15) = 1.92$, $p = .074$, but with a slight trend for the older group to be more accurate.

Age and performance in typical sample –

A significant negative correlation was found between age and the *average distance* from target, with the distance between target and stimulus reducing with age (becoming more accurate), for both typically developing children ($r(49) = -.293$, $p = .037$), and for children with ASD ($r(15) = -.507$, $p = .038$).

Matched sample descriptives

From the sample above, 14 typically developing individuals were matched to 14 individuals with ASD on WISC-IV raw scores. Descriptives are presented below.

Table 4.3: Descriptives for matched samples including *average distance* (standard deviation in brackets).

	N	Mean CA	Mean WISC raw score	Average Distance
TYP	14	10.64 (4.05)	93.64 (40.48)	1.34 (.472)
ASD	14	10.71 (3.22)	91.00 (40.53)	1.58 (.462)

There was no significant group difference in WISC raw score, ($t(26) = .173$, $p = .864$), and no significant age effect was found between groups ($t(26) = -.052$, $p = .959$).

Task performance –

An independent t-test revealed no significant group difference in *average distance* from target between the typically developing and ASD group, $t(26) = -1.34$, $p = .192$.

<u>*Direction of Shift*</u>

Overall sample descriptives

The second variable of interest was the *direction of shift* from the target variable. For each participant, the average distance from the target was calculated, retaining the sign (-/+). The number of individuals who scored negatively and the number of individuals who scored positively for each group are shown in the table 4.4 and 4.5 below (matched on WISC raw score as above).

Table 4.4: *Direction of shift* for each participant group, represented by number of individuals for entire sample.

	Negative	**Positive**	Total
TYP	38	13	51
ASD	7	10	17
Total	45	23	68

Analysis of the data in Table 4.4 using chi-square test revealed that positive/negative *direction of shift* was significantly associated with group, $X^2(1) = 6.33$, $p = .012$. The typical group had a significantly more negative *direction of shift* than would be expected, whereas the ASD group was more positive.

Matched sample descriptives

Table 4.5: *Direction of shift* for each participant group, represented by number of individuals for matched samples.

	Negative	**Positive**	Total
TYP	11	3	14
ASD	6	8	14
Total	17	11	28

The Table 4.5 above indicates that in matched samples, the overall direction of shift was negative (coarse texture response) across groups. However, when considering groups separately typically developing individuals tend to respond towards coarse texture (negative direction of shift), whilst the ASD group show minor variation in the direction of shift, but towards the finer texture (positive direction of shift). Analysis of the matched sample data in Table 4.5 using chi-square test of independence revealed that positive/negative *direction of shift* was not significantly associated with group, $X^2(1) = 3.74$, $p = .053$.

Conclusion

The fine texture matching task in Study 4 aimed to determine whether the reported differences in tactile sensitivity may be due to difficulty in cross-modal matching of texture or to a difference in perceptual range of discrimination. That is, perhaps individuals with ASD perceive a texture to be more or less coarse than typically developing individuals. The results did not find any significant group differences in the *average distance* from the target, suggesting that there is no difference in the range of perceptual sensitivity. *Direction of shift* examined whether individuals with ASD would perceive the visual stimulus as coarser or finer than the haptically explored texture. A significant group effect was found in the non-matched sample, with a negative direction of shift in the typical group, indicating a tendency to match the target stimulus to a coarser texture. Although no significant association between group and direction of shift was found with matched samples, the result was approaching significance (p = .053). The same trend is found in the pattern of results in non-matched and matched sample comparison, with typically developing group being more homogenous whereas the ASD group almost divided equally between negative and positive shift. In conclusion, the results of the study suggest that both groups do not differ in their ability to match *fine texture* cross-modally, and perceptual intensity of the texture is not significantly different between typically developing individuals and those with autism. However, it is worth noting that given the small numbers of participants in the matched comparison and the similar patterns of results when comparing to the whole sample, there appears to be something unusual going on in the autism sample when matching texture cross-modally, i.e. they appear not to have the same bias towards coarser texture as the typically developing individuals.

4.3. Cross-modal matching of everyday textures

The following study explores cross-modal matching of everyday textures. The anecdotal reports of unusual tactile response are about textures individuals come into daily contact with, such as cotton shirts, satin labels, woolen jumpers and grass. The TPAQ examined preference ratings of all textures that individuals are most likely to come into contact, including those that are reported to be not liked / liked very much by individuals with autism. Yet, no extreme texture preferences or aversions were found using the TPAQ. Therefore, it is proposed that these unusual tactile responses are not due to the type of texture, but due to a possible mismatch of expectation of what the texture looks and feels like. Results from Study 4 found no group difference in fine texture matching. However, it could be suggested that since all the texture trials (both visual and haptic) were fine texture and very similar, it is unlikely to have caused a mismatch of expectation.

4.3.1 *Pilot Study 5.1*

The pilot study explored texture matching with typical and atypical children. The purpose was to determine the appropriate level of difficulty in matching texture.

Participants

Twenty typically developing children (mean age = 9.35, age range 7 to 11 years old) and three male individuals with autism (mean age =11.28) were recruited from a local school in North Tyneside.

Materials:

The materials consisted of 8 visual targets that were ecologically relevant textures; fur, wool, coarse sandpaper, wood, lace, play-dough, bark, cotton (see Table 4.5 below). The textures were 5cm x 5cm wide and approximately 1cm thick. The tactile stimuli were divided into 8 'hard' (difficult) distracters and 8 easy distracters that were paired with the visual target. For example, fur was paired with either fleece (hard distracter) or grass (easy distracter). These pairs made up the 16 *Different* trials. The Same trials consisted of the 8 visual targets paired with the same corresponding tactile textures, e.g. Fur – Fur. There were 24 trials in total.

Table 4.5: *Visual and Tactile stimuli for each trial type.*

Visual Target	**Tactile EASY**	**Tactile HARD**	**Tactile SAME**
FUR	GRASS	FLEECE	FUR
WOOL	TISSUE	CARPET	WOOL
SANDPAPER (coarse)	WAX	SANDPAPER (fine)	SANDPAPER (coarse)
WOOD	MARBLE	TIGHTS	WOOD
LACE	HAIR	VELVET	LACE
PLAYDOUGH	SILK	RUBBER	PLAYDOUGH
BARK	SPONGE	LEATHER	BARK
COTTON	ROUGH PLASTIC	SMOOTH PLASTIC	COTTON

Procedure:

The child was seated, and the aim of the task was explained to the child with the instruction "not to touch the texture on top of the box, and not to look inside the box. The experimenter checked that the child was still happy to help with the research.

Only one hand could be used, the preferred / dominant hand, throughout the experiment. The choice of hand was determined at the beginning of each session by asking the child "what hand do you write with?" If the child was unable to answer L/R, the child was asked to write or draw something; the hand spontaneously employed was considered the preferred hand. The child was then given the instruction to "put that hand under the cloth please". A texture was then placed on top of the box. The child was told they could only look at the texture. Another texture was placed simultaneously inside the box for the child to haptically explore. The instruction was to use only their index finger. They could feel the texture in any direction and for as long as they needed to respond to the question "Is the texture [on top] the same or different [to the one inside the box]?" The question was repeated for each trial. On rare occasions, some children required positive encouragement to continue the task.

Results: The texture comparison was found to be too easy. The maximum score was 24, with matching accuracy in the ASD group (M = 21.43), and typically developing group (M = 22.82), being close to ceiling effect.

Conclusion

Pilot Study 5.1 revealed that if the participant had previously felt a texture which was the same as the visual target, they were then easily able to determine whether the felt texture was the same or different to a new subsequent visual target. For example, if the visual stimulus was Fur and the tactile texture was Fur (Same trial), a subsequent texture pair of Fleece (visual) – Fur (tactile) would be easily identified as being different. Participants stated that they could remember what the texture felt like, and this influenced consecutive trials. Having two matches for the same visual target also increased likelihood of accurately matching on the subsequent trial. This flawed design resulted in ceiling effects. In the final version of the study separate 'same' and 'different' trials were used and additional Blocks were added for increased difficulty (details presented below).

4.4 Study 5

Method

Participants:

105 typically developing children took part in the study (mean age = 9.34, age range 5 to 14 years old). They were recruited from local North Tyneside schools. Nineteen individuals diagnosed with Autism agreed to participate (mean age = 11.56, age range 5 to 14 years old). Of the nineteen, only 11 were matched to typically developing individuals to be included in the comparison. Twelve individuals with ADHD were involved in the research (mean age =11.82, age range 8 to 14 years). Of these, only 11 were matched to the typically developing individuals to be used in the comparison analysis. All children in the ASD and ADHD group had previously received a clinical diagnosis by experienced clinicians using the guidelines of standard criteria (DSM-IV; American Psychiatric Association, 1994). Ethics for the study was approved by the local ethics committee at Newcastle University.

Design:

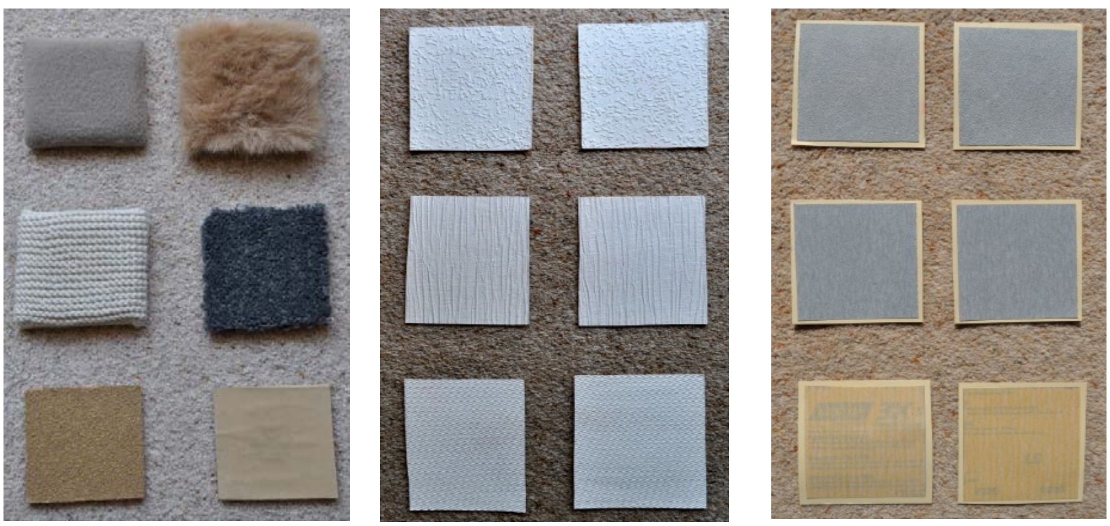
A mixed design was used. Group was the between-subjects factor and task the within-subjects factor which has 3 levels of difficulty in texture matching; Easy Medium and Hard. Accuracy of matching texture cross-modally was the dependent variable, recorded as total percentage correct, hit rate and *d´*.

Materials:

The materials were divided into 3 blocks of difficulty, Easy, Medium and Hard. Levels of difficulty were determined by likely detectible differences. The texture items used for visual-haptic matching in the Easy Block were taken from the TPAQ (refer to Study 1). These textures were used as they have easily identifiable differences. Of the 31 items, 16 textures were used in same and difference trials (Table 4.6). The stimuli for the Medium Block were patterned wallpaper sheets. These were the same as those used in Study 3. Hard Block trials were sandpaper sheets, chosen as they had the least discernible differences. See figure 4.2 below for photographs of some of the textures used.

Table 4.6: Textures used for *different* and *same* trials in EASY Block

Different trial textures		Same trial textures	
Visual stimulus	*Tactual stimulus*	*Visual stimulus*	*Tactual stimulus*
Fur	Fleece	Grass	Grass
Wool	Carpet	Silk	Silk
Playdough	Rubber	Tissue	Tissue
Cotton	Smooth plastic	Tights	Tights
Wax	Marble	Rough plastic	Rough plastic
Velvet	Lace	Wood	Wood
Bark	Leather	Sponge	Sponge
Coarse Sandpaper	Smooth Sandpaper	Hair	Hair



EASY MEDIUM HARD

Figure 4.2: *Photographs of some of the textures used in Easy, Medium and Hard condition*

Procedure:

The procedure was identical to the pilot study (above). The child was seated, and the aim of the task was explained to the child with the instruction "not to touch the texture on top of the box, and not to look inside the box. The experimenter checked that the child was still happy to help with the research. The child was only allowed to use one hand, the preferred / dominant hand, throughout the experiment. The choice of hand was determined at the beginning of each session by asking the child "what hand do you write with?" If the child was unable to answer L/R, the child was asked to write or draw something; the hand spontaneously employed was considered the preferred hand. The child was then given the instruction to “put that hand under the cloth please”. A texture was then placed on top of the box. The child was told they could only look at the texture. Another texture was placed simultaneously inside the box for the child to haptically explore. The instruction was to use only their index finger. They could feel the texture in any direction and for as long as they needed to respond to the question “Is the texture [on top] the same or different [to the one inside the box]?” The question was repeated for each trial. On rare occasions, some children required positive encouragement to continue the task. See figure 4.3 below for illustration of procedure used.

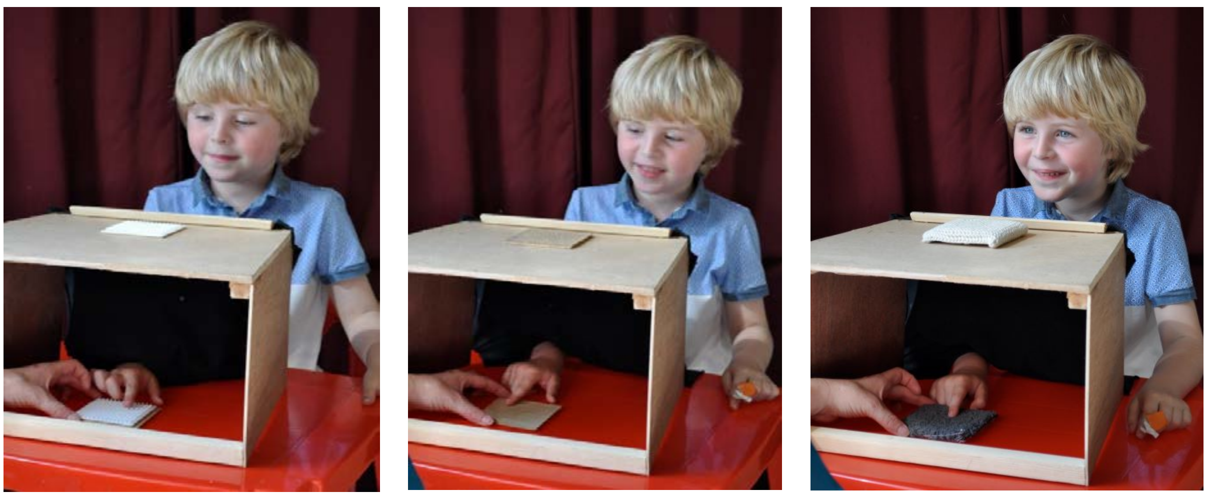


Figure 4.3*: Demonstration of the cross-modal method used.*

Data Analysis:

Total proportion correct was calculated for each level of difficulty; Easy, Medium and Hard. Hit rate was defined as saying “different” when two textures were different. As a measure of sensitivity in discrimination *d'* was calculated by using the following equation: d’ = z(H)-z(F). Bias in discrimination was calculated using the following equation: c = - [z(H) + z(F)]/2.

All data was checked for normality before analysis carried out.

Results

Sample Descriptives

The typical sample consisted of 105 individuals, 66 females and 39 males. The ASD sample consisted of three females and 16 males. The ADHD sample (N=12) consisted entirely of males. The descriptive statistics are presented in Table 4.7 below.

Table 4.7: *Descriptive statistics for total proportion correct for entire sample (standard deviation in brackets).*

Group	N	Total Proportion Correct
TYP		
5-7 years	43	0.77(.068)
8 -9 years	47	0.81(.063)
10- 14 years	15	0.79(.054)
ASD		
5-7 years	1	0.56
8 -9 years	7	0.62(.087)
10- 14 years	11	0.63(.090)
ADHD		
8 -9 years	1	0.78
10- 14 years	11	0.76(.084)

Exploring age differences in the typical sample

Typical sample (N=105)

One-way between groups ANOVA revealed significant age differences in Total Proportion Correct, ($F(2,102) = 5.41$, $p = .006$). Post hoc multiple comparisons using Dunnett T3 found significant differences between the 5-7 year-old group and 8-9 year old group ($p = .001$), but no other significant group difference was found.

Exploring age differences in the atypical samples

ASD sample (N=18)

No significant age difference was found between the 8-9 year old group and 10-14 year old group for Total Proportion Correct in the ASD sample ($t(16) = -.16$, $p = .90$).

ADHD sample (N=12)

Age differences were not explored in the ADHD sample given the restricted age range of the sample.

Exploring discrimination sensitivity in the typical sample

Sensitivity measure (d') -

ANOVA was carried out and found that discrimination sensitivity (*d'*) was significantly different across the levels of task difficulty ($F(2,208) = 270.04$, $p < .001$), with highest sensitivity in the Easy level (M = 2.37) and lowest sensitivity in the Hard level (M =.71).

Response bias measure (c) –

ANOVA was carried out to explore response bias *(c)* across level of difficulty, and was found to be significant ($F(2,208) = 32.86$, $p < .001$). Lowest bias was found in the Easy level (M = .28) and highest bias in the Hard level (M = .38). The level of bias was fairly conservative across all conditions.

Typical, ASD and ADHD sample comparison

For group comparisons, typical, ASD and ADHD participants were matched on general ability score (WISC). Summary scores are presented in Table 4.7 below. Both the ASD and ADHD group consisted entirely of males, and the typical group consisted of 17 males, and 5 females.

Table 4.8: *Average scores for matched participant groups (standard deviation in brackets).*

	N	*Mean CA*	*WISC score*	*Total proportion correct*
TYP	22	9.67 (1.15)	86.09 (5.54)	.80 (.064)
ASD	11	11.01 (2.68)	76.34 (8.22)	.66 (.089)
ADHD	11	11.25 (1.32)	89.64 (9.34)	.77 (.080)

Individuals from the ASD and ADHD group were matched to a typical individual using WISC-IV scores for two verbal and two non-verbal subscales, resulting in a total WISC raw score. A one-way ANOVA revealed no difference in WISC score across groups, ($F(2,41) = .705$, $p = .50$).

Sensitivity measure (d') -

A further mixed model ANOVA was carried out to determine whether discrimination sensitivity *(d')* was significantly different between groups for each level of task difficulty. A main effect of level of difficulty was found (F(1.6,67) = 94.99, *p* <.001), with highest sensitivity in the Easy level (M = 2.13), and lowest sensitivity in the Hard level (M = .336). A significant main effect of group was found (F(2,41) = 10.60, *p* <.001), with highest sensitivity found in the typical group (M = 1.41) and lowest sensitivity found in the ASD group (M = .69). Pairwise comparisons found significant differences between the Typical and ASD group (*p* <.001), and the ASD and ADHD group (*p* <.01), but no significant difference was found between the Typical and ADHD group (*p* = .396). No significant interaction was found between group and sensitivity across level of difficulty. Results are presented in Figure 4.4 below.

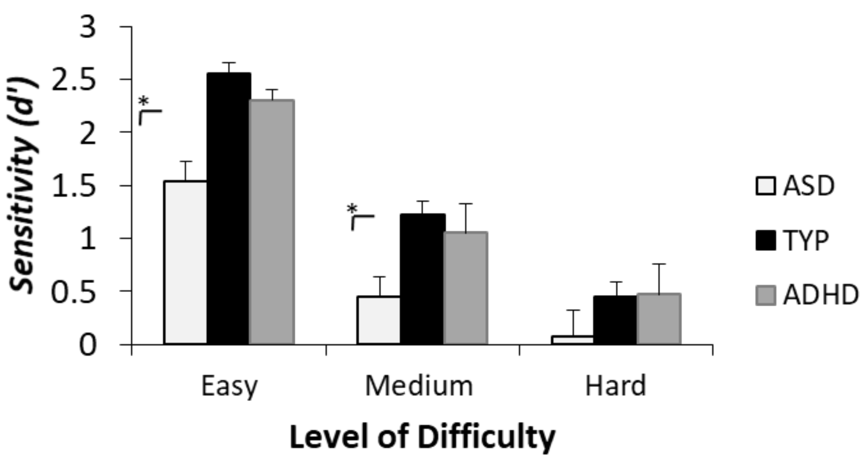


Figure 4.4*: Clinical group comparisons for cross-modal task across level of difficulty (error bars represent standard error).*

Response bias measure (c) -

ANOVA was carried out to explore response bias between groups across level of difficulty and was found to be significant (F(2,82) = 7.29, *p* = .001), with lowest bias observed in the Easy level (M = .338) and highest bias observed in the Hard level (M = .593). A main effect of group was found (F(2,41) = 10.11, *p* <.001), with highest bias in the ASD group (M =.70) and lowest bias in the ADHD group (M = .43). Pairwise comparisons found significant differences in bias between the Typical and ASD group (*p* <.01), ASD and ADHD group (*p* <.001) and between the Typical and ADHD group (*p* = .045) A significant interaction was found between group and bias across level of difficulty (F(4,82) = .271, *p* <.05). Typical group appears to increase in bias as level of difficulty increases, whereas ASD appears to remain high, and ADHD remain low across levels. *Therefore, typically developing individuals becoming more conservative in their response with increased level of difficulty.* The results are presented in Figure 4.5 below.

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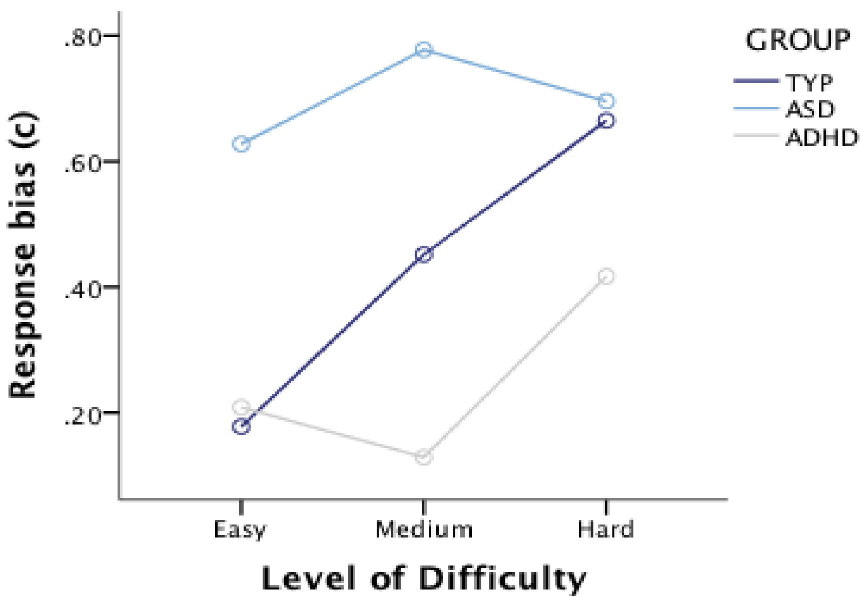

Figure 4.5: *Response bias for participant groups across level of difficulty.*

Conclusion

Study 5 found a significant group difference in visual-tactile matching of everyday textures. Individuals with autism performed significantly less accurately than typically developing individuals and those with ADHD. No difference in performance was found between typically developing individuals and those with ADHD.

4.5. Study 6: Cross-modal follow-up controlling for exposure time

A possible criticism of Study 5 is whether the result was due to differences in amount of tactile contact (exposure) with the texture between the typical and atypical group. That is, perhaps individuals with autism spent less time exploring the texture than the typically developing individuals resulting in less accurate matching. That is if they do not like the feel of the texture, they are likely to spend less time exploring it. The follow-up study presented below aimed to control for exposure time by limiting the amount of time the participant could haptically explore the texture. Since the ADHD group performed at the same level of accuracy as the typically developing group, and significantly different to the ASD group, they were excluded from further studies.

Method

Participants:

Fifty-seven typically developing children (Mean age = 8.22, age range 4 to 15 years old) and 12 individuals with ASD (Mean age = 12.29, age range 7 to 15 years old) were recruited from local schools in the North East of England. All children were recruited through schools in the North East of England. All children in the ASD group had previously received a clinical diagnosis of autism by experienced clinicians using the guidelines of standard criteria (DSM-IV; American Psychiatric Association, 1994). Ethics for the study was approved by the local ethics committee at Newcastle University.

Design:

This was the same as Study 5 was used, with the IV being level of difficulty of texture trials, and the dependent variable *proportion correct.*

Procedure:

The procedure was the same as the original study detailed above (Study 5), except for an additional control measure. The child was not allowed to freely explore the tactile texture (inside the box), and instead the texture was dragged by experimenter three times beneath the participant's index finger at a pace of approximately 1 stroke per second. The question then followed "Is the texture the same or different?".

Results

Descriptive statistics across age groups for total proportion correct are presented below.

Table 4.9: *Descriptives cross separate age groups* (TYP N = 57, ASD N = 12; standard deviation in brackets).

Group	*N*	*Mean AGE*	*Total Proportion Correct*	*WISC raw score*
TYP				
4-6 years	23	5.05 (.52)	.64 (.08)	41.89 (15.27)
7-9 years	19	7.42 (.84)	.68 (.04)	65.16 (18.13)
10-15 years	15	13.23 (1.52)	.70 (.04)	131.07 (13.30)
ASD				
7-9 years	12	8.25 (.35)	.65 (.03)	79.50 (3.53)
10-15 years	10	13.00 (1.88)	.63 (.11)	90.80 (22.82)

Age group difference in Total Proportion Correct -

Typical sample (N=57):

A one-way ANOVA found a main effect of age in the typical sample ($F(2,50) = 4.83$, $p = .012$). Post hoc comparisons found significantly lower scores in the 4-6 year-old group compared to the 7-9 year-old group ($p = .03$) and 10-16 year-old group ($p = .02$). No difference was found between the 7-9 year-old and 10-16 year-old group ($p = .42$).

ASD sample (N=12):
Age differences were not explored in the ASD sample given the small sample sizes.

Matched sample comparison

Descriptives for each sample, including sensitivity and bias scores for each Block are presented below in Table 4.10.

Table 4.10*: Unmatched and matched sample descriptives and sensitivity measures across both blocks (mean with standard deviation in brackets).*

			EASY BLOCK		**MEDIUM BLOCK**	
Group	N	Mean CA	*d'*	*c*	*d'*	*c*
Unmatched						
TYP	57	8.22 (3.48)	2.60 (1.17)	1.06 (.69)	1.54 (1.94)	1.21 (1.15)
ASD	12	12.21(2.52)	2.27 (1.20)	.91 (.90)	1.99 (1.85)	.66 (1.95)
Matched						
TYP	11	7.89 (3.33)	3.11 (.79)	.83 (.92)	2.21 (1.99)	1.45 (1.19)
ASD	11	12.59 (2.25)	2.19 (1.23)	.85 (.85)	1.97 (1.94)	.54 (2.00)

Clinical comparison groups were matched on WISC IV raw scores. Sample details in Table 4.11 below.

Table 4.11: *Matched sample non-verbal and WISC raw scores (mean with standard deviation in brackets).*

Group	N	Mean CA	Non-verbal Score	Verbal Score	WISC raw Score
TYP	11	7.89 (3.33)	43.36 (19.84)	42.73 (14.58)	86.09 (33.45)
ASD	11	12.59 (2.25)	48.09 (13.46)	41.91 (12.33)	90.00 (21.81)

No group difference was found for non-verbal ability (t(20) = -.65, *p* =.52), for verbal score (t(20) = .14, *p* =.89), nor for total WISC raw score (t(20) = -.33, *p* = .75).

Exploring total proportion correct in matched comparison

A significant group difference was found in proportion correct, with better matching accuracy in the typically developing group (M = .72) than the ASD group (M = .63), t(20) = 2.64, *p* = 0.02).

Exploring performance using sensitivity measure d′

A mixed model 2x2 ANOVA found no significant main effect of *level of difficulty* (F(1, 20) = 2.21, *p* =.152). No main effect of group was found (F(1, 20) = 1.53, *p* =.23) and no interaction between level of difficulty and group (F(1, 20) = 2.34, *p* = .33). However, when Easy and Medium condition were explored separately, a significant group difference was found in the Easy condition (t(20) = 2.37, *p* = .028) with higher performance in the typical group, but no difference found in the Medium condition (t(20) = .15, *p* = .88).

4.6. Combining Study 5 and 6 to explore effects of exposure time on performance

To further explore whether individuals with autism performed more poorly due to differences in exposure, samples from Study 5 and Study 6 were combined.

*Participants and Design***:** Eleven individuals with autism and 11 typically developing individuals from Study 5 were combined with 11 ASD and 11 typically developing individuals from Study 6. These groups were previously matched on WISC raw score. Therefore, there were 22 individuals in each group; TYP, ASD, No control, Exposure Control. The dependent variable used was *proportion correct* (refer to Table 4.12 and 14.13 below).

Sample descriptives

Table 4.12: *Age, WISC score and Total Proportion Correct for Group (mean and standard deviation in brackets).*

Group	N	Mean CA	WISC raw Score	Total Proportion Correct
TYP	22	8.14 (2.23)	86.82 (30.76)	.76 (.06)
ASD	22	11.57 (2.31)	83.14 (24.61)	.64 (.10)

Table 4.13: *Age, WISC score and Total Proportion Correct for Exposure (mean and standard deviation in brackets).*

Exposure	N	Mean CA	WISC raw Score	Total Proportion Correct
No Control	22	9.41 (1.97)	81.91 (27.86)	.72 (.11)
Yes Control	22	10.30 (3.49)	88.04 (27.63)	.68 (.09)

No group differences were found in WISC raw score for both Group comparison (TYP and ASD; t(42) = .44, *p* = .66), nor for Exposure condition (NO control and YES control; t(42) = -.73, *p* = .47).

Differences in total proportion correct

Exploring differences in *total proportion correct*, a 2 x 2 factorial ANOVA found no significant group effect between Exposure Control and No Exposure Control (F(1,40) = 3.51, *p* = .07). There was a significant group effect in performance between the typical and ASD group (F(1,40) =20.12, *p* <.001), and no significant interaction between comparison group and Exposure Control (F(1,40) = .82, *p* = .37).

Conclusion

The results show *no main effect of exposure control*, which means that controlling for contact time on the stimulus does not affect accuracy in matching. A significant group effect in total proportion correct found that individuals with ASD perform worse on the matching task compared to the typically developing group across both studies. No significant interaction shows that controlling for exposure does not affect performance for either TYP or ASD group. It can be concluded, with some confidence that exposure time cannot account for the differences in group performance.

4.7 Study 7: Cross-modal matching of shape and texture

The previous studies explored differences in visual-tactual matching of texture in typical, ASD and ADHD groups. Since some evidence of a group difference was found, with ASD group performing worse at matching texture than the two other groups, the following study was designed to explore possible differences in cross-modal matching of global shape compared to texture between ASD and typically developing individuals, The following study aims to determine whether it is specifically texture that individuals with ASD find difficult to match cross-modally.

Method

Participants:

Sixty-one typically developing children (Mean CA = 9.63, age range 4 to 16 years old) and 16 children with ASD (Mean CA = 10.98, age range 7 to 16 years old) participated in the study. They were recruited from schools in the North East of England. All children in the ASD group had previously received a clinical diagnosis of autism by experienced clinicians using the guidelines of standard criteria (DSM-IV; American Psychiatric Association, 1994). Ethics for the study was approved by the local ethics committee at Newcastle University.

Design:

A mixed-design was used, with group as the between-subjects factor and task as the within-subjects factor. Accuracy of matching texture and shape cross-modally was the dependent variable, recorded as total percentage correct, hit rate and d' for texture and shape separately.

Materials:

The materials consisted of 6 shapes and 6 textures (refer to Figure 4.6 below for picture of shapes used). Texture pairs were 1) fleece – fur, 2) coarse – fine sandpaper, and 3) high complex wallpaper– medium complex wallpaper.

Procedure:

The study was dived into three tasks, a visual matching task, tactile matching task and a visual-tactile matching task. Identical stimuli were used for the visual only and tactile only task. Each task is described below.

1. **Separate visual only and tactile only matching task**:

Participants first completed a visual only and tactile only task. Identical stimuli were used for the visual only task and tactile only task. In the visual only task, participants were shown two shapes simultaneously. In the tactile task, two shapes were presented inside a box to occlude vision. Participants were allowed to freely explore the shapes using both hands. The experimenter encouraged the participant to feel the outline / edges of the shape when determining shape differences, and "lateral motion" was encouraged when asked about texture differences. Two questions were asked independently in separate blocks - Are they the same shape? Are they the same texture? There were 6 trials for shape and 6 trials for texture in the visual and tactile task. Two trials were Different, 2 trials the Same, and in 2 trials the texture was either the same and the shape was different, or the texture was different and the shape the same (see below for detailed description of trial type). Trials were presented in a random order.

2. **Cross-modal task:**

At the start of the cross-modal task, 3 practise trials were administered to familiarise the child with the task. These trials were not included in the experimental blocks.
Participants were presented with stimuli in two Blocks; SHAPE and TEXTURE. This refers to whether participants were asked specifically about shape or texture. For example, in the Shape Block participants were asked "Are they the same shape or are they different?".
Each block consisted of 6 same-same trials; 6 different-different trials; 6 mixed (different-same) trials. *Same-same* (SS) trials refer to stimulus pairs that have the same shape and same texture. *Different-different* (DD) trials refer to stimulus pairs that differ in shape and differ in texture. *Mixed* (DS) trials refer to stimulus pairs where either the texture is the same and the shape is different, or the texture is different, and the shape is the same (see figure 4.6 below). For this trial type (*Mixed*) the correct response switches depending on Block (Shape / Texture). There were 18 trials for the SHAPE Block and 18 trials for TEXTURE Block, total 36 trials. The visual target (textured shape) was presented on top of the box, and the tactile stimulus was presented inside the box to be haptically explored with both hands. The participants could take as long as they needed to respond to the question 'Are they the same [Shape / Texture] or are they different?'. Trials were presented randomly within each block. Frequency of shape type and texture was balanced across visual and tactile positions. However, this proved difficult to control for in the *Mixed* trials resulting in uneven numbers of correct 'same' response and correct 'different' response for the

Shape and Texture Block. That is, in the Texture Block there were 2 ‘different’ correct responses, and 4 ‘same’ correct responses. Whereas in the Shape Block, there was 2 ‘same’ correct responses and 4 ‘different’ correct responses.

Same- Same *Different -Different* *Same -Different*

Figure 4.6: *Photograph of textured shapes used in Same, Different and Same-Different trials.*

Data Analysis

All data was checked for normality before any analysis carried out.

Results

Visual ONLY and Tactile ONLY task results:

All participants performed at ceiling in both the visual only and tactile only task (see Table 4.14 below). Max score of 6 for each trial type e.g. visual shape, and a total of 12 for each task ie. Visual and Tactile task.

Table 4.14: *Mean proportion correct for shape and texture trial type in separate Visual and Tactile Task (standard deviation in brackets).*

			VISUAL		**TACTILE**	
Group	**N**	**Mean CA**	**Shape**	**Texture**	**Shape**	**Texture**
TYP	61	8.44 (3.03)	.95 (.10)	.92 (.12)	.87(.13)	.86 (.12)
ASD	16	12.96 (2.91)	.92 (.11)	.91 (.12)	.91 (.15)	.87 (.12)

Exploring differences in matching of shape and texture in the Visual Task and the Tactile Task for each comparison group using proportion correct

Typical sample

A 2 x 2 within-subjects ANOVA found a significant main effect of Modality, with better matching in the visual task (M = .93) compared to the tactile task (M = .87), F(1,59) = 20.25, *p* <.001. No significant main effect of Stimuli Type (shape or texture) was found (F(1,59) = 2.14, *p* = .15). No interaction was found between Stimuli Type (shape and texture) and Modality (visual and tactile), F(1,59) = .94, *p* =.34.

ASD sample

A 2 x 2 within-subjects ANOVA found no main effect of Modality, F(1,14) = .453, *p* =.51. No main effect of stimuli type (shape or texture) was found, F(1,14) = .599, *p* = .45). No interaction was found between stimuli type (shape and texture) and Modality (visual and tactile), F(1,14) = .17, *p* = .69.

***Cross modal task results**:*

The sample descriptives for typical and atypical age comparisons on the cross-modal task are presented in Table 4.12 below.

Table 4.15: *Sample descriptives for age groups 4-6 years, 7-9 years, and 10-15 years (standard error in brackets).*

				SHAPE	**TEXTURE**
Group	*AGE GROUP*	*N*	*Mean CA*	*Proportion Correct*	*Proportion Correct*
TYP	4-6 years	27	5.63	.86(.02)	.82(.02)
	7-9 years	29	8.48	.89(.02)	.86(.01)
	10-16 years	5	14.8	.94(.02)	.86(.05)
ASD	7-9 years	4	8.13	.85(.03)	.79(.05)
	10-16 years	12	13.83	.88(.02)	.80(.03)

Age differences in the typical sample were explored using percentage correct for SHAPE and TEXTURE and are shown below.

Age Difference in Typical sample-

A repeated measures ANOVA found a main effect of stimuli, with better performance in the SHAPE condition (Mean = .90, SE = .016), compared to the TEXTURE condition (Mean = .85, SE = .015), F(1,58) = 6.86, *p* = .011. No significant age effect was found, and there was no interaction between age and stimuli.

Age differences were not explored for the ASD sample due to small N.

Possible differences in performance across trial type were then explored for each group

Data was then organised according to trial type for both the SHAPE and TEXTURE Block (details in Table 4.16 below).

Table 4.16: *Descriptives for entire sample across both SHAPE and TEXTURE condition, and all trial types (TYP N=61, ASD N=16; standard deviation in brackets).*

	SHAPE			**TEXTURE**		
Group	Same-Same	Diff-Diff	Same-Diff	Same-Same	Diff-Diff	Same-Diff
TYP	5.57 (.09)	5.20 (.096)	5.15 (.107)	5.67 (.073)	3.92 (.178)	5.61 (.091)
ASD	5.62 (.202)	5.00 (.204)	5.06 (.170)	5.63 (.256)	3.31 (.425)	5.44 (.203)

The *Same-Different* trials were split further by the response type ‘same’ or ‘different’ (as described above). Due to uneven trial numbers *total proportion correct* has been used instead of total score for the descriptive statistics in the Table below.

Table 4.17: *Proportion Correct for Shape and Texture Block for MIXED trials split by same / different response (standard deviation in brackets).*

	SHAPE		**TEXTURE**	
Group	Same	Different	Same	Different
TYP	.86 (.26)	.80 (.20)	.93 (.12)	.94 (.21)
ASD	.91 (.20)	.78 (.15)	.94 (.11)	.84 (.30)

Table 4.17 illustrates that matching performance in the Shape and Texture Mixed Trials was very accurate, both when the correct response is *same* and when it is *different*.

Performance in the typical sample (N=61):

A repeated measures ANOVA found a significant effect of trial type in the SHAPE condition, F(2,120) = 7.65, *p* =.001. Pairwise comparisons found significant differences between SS and DD (*p* = .005), between SS and DS (*p* = .001) trial type, but no difference between DD and DS trial types (*p* = .643).

A repeated measured ANOVA found a significant effect of trial type in the TEXTURE condition, F(2,120) = 60.63, *p* <.001. Pairwise comparisons found significant differences between SS and

DD (*p* <.001), DD and DS (*p* <.001), whereas no significant difference between SS and DS (*p* = .47).

Performance in the ASD sample (N=16):

A repeated measures ANOVA found no effect of trial type in the SHAPE condition F(2,30) = 3.124, *p* = .06. A repeated measures ANOVA found a significant effect of trial type in the TEXTURE condition, F(2,30) = 16.32, *p* <.001. Pairwise comparisons found significant differences between SS and DD (*p* <.001), DD and SD (*p* = .001), whereas no significant difference between SS and DS (*p* = .594).

It is apparent from this analysis that both typically developing individuals and those with Autism perform worse on Different-Different trials in the TEXTURE condition.

Matched sample comparison

Table 4.18: *Sample descriptives for group matched on WISC IV raw score (standard deviation in brackets).*

				SHAPE	**TEXTURE**
Group	*N*	*CA*	*Mean WISC IV*	*Proportion Correct*	*Proportion Correct*
TYP	13	8.38	84.92	.91 *(.03)*	.87 *(.02)*
ASD	13	11.96	83.85	.85 *(.017)*	.78 *(.03)*

Using the total scores for each condition (Shape and Texture), a repeated measures ANOVA found a significant main effect of stimuli, F(1, 24) = 5.75, *p* = .025, with performance being more accurate in the SHAPE condition (Mean = 15.85, SE = .29), than the TEXTURE condition (Mean = 14.85, SE = .33). A significant group effect was found, F(1, 24)=7.9, *p* = .01, with the TYP group (Mean = 16.00, SE = .33) performing better than the ASD group (Mean = 14.69, SE = .33). No interaction between group and stimuli was found.

Note: *The lack of significant interaction is likely be due to the weak power with the small sample (partial Eta Squared = .013). Independent t-tests reveal significant group differences for the TEXTURE condition, and no significant group difference in the SHAPE condition.*

Using d′ as a measure of sensitivity-

Due to difficulty separating Same and Different trials in the Mixed Trial condition (which is either same shape and different texture / different shape and same texture – I have only calculated the d′ for shape and texture condition using scores from the SS and DD trials.

Table 4.19: *Sample comparisons for measures of sensitivity in shape and texture condition (standard deviation in brackets).*

		SHAPE		**TEXTURE**	
Group	*N*	*d'*	*c*	*d'*	*c*
Unmatched					
TYP	61	4.04 (.21)	.32 (.10)	3.07 (.17)	.94 (.11)
ASD	16	3.96 (.36)	.52 (.21)	2.7 (.36)	1.2 (.24)
Matched					
TYP	13	4.10 (.50)	.15 (.21)	3.12 (.25)	1.05 (.16)
ASD	13	3.45 (.29)	.64 (.26)	2.5 (.42)	1.23 (.29)

Unmatched comparison:

A repeated measures ANOVA found a main effect of stimuli type, with SHAPE performance (Mean d' = 4.0, SE = .22) being significantly better than TEXTURE performance (Mean d'= 2.9, SE = .19), F(1,75) =16.20, p <.001. No significant group effect was found, nor interaction.

Matched comparison:

The same pattern of results was found in the matched comparison. A repeated measures ANOVA found a main effect of stimuli type, with SHAPE performance (Mean d'= 3.78, SE = .29) being significantly better than TEXTURE performance (Mean d'= 2.8, SE = .24), F(1,24) = 7.83, p <.001. No significant group effect was found, nor interaction.

Response Bias (c) -

There were no group differences found in either unmatched or matched comparisons. There was however, a significant effect of bias on stimuli type, for both comparison samples. Higher bias was found in the TEXTURE condition (Mean c = 1.1 for both comparisons), than in the SHAPE condition (Mean c = .42 and .29 for the unmatched and matched comparison respectively). It appears that all individuals, are more likely to say the textures are the "same", even when they are not.

Conclusion

In the shape and texture task a significant group effect was found with *total proportion correct*, with more accurate visual-tactual matching in typically developing individuals compared to individuals with autism. However, using a more sensitive measure of discrimination (d'), the group effect disappears. This may be due to the small number of trials in the task. The limited number of trials reduces the range of possible scores, which could affect the sensitivity in finding a significant difference. The results also found significantly more accurate performance in the shape condition than in the texture condition for both groups. When considering trial type, matching accuracy was lowest in the Texture *Different-Different* trials for both the typically developing group and the ASD group. All participants appear to be doing something unusual when matching in these trials.

4.8 Introduction to Study 8 - Meaningful texture matching

Use of context in ASD

Over a number of years, it has been shown that individuals with ASD are less likely than typical matches to use context information. The theory of Weak Central Coherence (WCC; Frith 1989) has been put forward as an explanation to these findings. Typically developing children and adults process information for meaning at the expense of details or surface structure, and this is referred to as 'central coherence'. By comparison, individuals with autism show a bias for featural and local information, and therefore show *weak central coherence*, with a failure to see the 'whole'. The original account has since changed from a deficit to an emphasis on superiority in local or detail-focussed processing i.e. not a failure to extract global form and meaning, but rather a processing bias or cognitive processing style (Frith & Happé, 1994). The framework of WCC has been used to explain superior performance on particular visuo-spatial tasks in autism, e.g. Block Design and Embedded Figures Test (Shah & Frith, 1983; Happé, 1994), with the successful completion of such tasks requiring one to resist forming a global representation of the visual stimuli and focus on the local (single) elements.

The distinction between *perceptual coherence* and *conceptual coherence* was first highlighted by Jolliffe and Baron-Cohen (2001) who explored WCC at the visuo-conceptual level. Previous evidence for WCC has been explored at the perceptual level (low-level integration) using mainly abstract, meaningless visual stimuli, such as Navon, Hidden Figures Task or Block Design (eg. Shah & Frith, 1983), in which the context is irrelevant. Studies like these further supporting the evidence for impaired *perceptual coherence* in autism, involving what Happé (1997) referred to as low-level meaning / low -level integration rather than conceptual coherence. Jolliffe and

Baron-Cohen (2001) explored conceptual coherence with adults with autism or Asperger syndrome. In study 1 individuals were required to visually integrate objects to create a coherent scene (from 5 individual stimuli, one of which was incongruent), and in study 2 participants were asked to identify the inappropriate item (odd item) from the visual scene (line drawing). For example, participants were asked to identify the butterfly sitting on the shovel in a snow scene. Results suggest that individuals with autism show a difficulty in conceptually integrating the objects into a coherent scene, and show an impairment in identifying the inappropriate item, supporting a 'global' deficit suggested by Frith's WCC. The authors argue that perhaps, based on their findings, that WCC and enhanced local processing may not work alongside each other, as the results showed that individuals with autism exhibited both a deficit to form a coherent whole, and a difficulty to identify parts (in the odd item task).

However, there is some evidence that individuals with autism do use context information and can extract meaning from pictures and words. Using the Stroop paradigm, Eskes, Bryson and McCormick (1990) found that individuals with autism showed the same degree of word interference as the matched control group in the colour naming task, demonstrating that individuals with autism are unable to inhibit semantic meaning from single words, thus negatively affecting performance. More recently, López and Leekam (2003) conducted a study exploring whether children with autism were impaired at using context information. Results from a series of experiments showed that visual context information facilitated performance in ASD, and they were able to use verbal context information for identification and categorisation in a verbal task. In the visual task, children were presented with visual pictorial context information, ie. a picture of a kitchen. This was followed by either an object likely to be found within that scene (e.g. a toaster) or unlikely (e.g. a drum). Difficulties were only found when having to use context to disambiguate written homographs. These findings do not support the claim of WCC that individuals with ASD have global deficits in 'connected meaning' as individuals with ASD did not show a difficulty using context information. The authors argued that perhaps WCC may only be relevant to verbal semantics.

There is evidence that individuals with other developmental disorders can also use context information. Hsu (2013a) used pictures to explore the effect of context information with individuals diagnosed with William's Syndrome (WS). Pictures of common scenes (using real photographs) were visually presented, then followed by a visual target item that was either congruent or incongruent to the background picture e.g. presented with a picture of a pharmacy, and then a hammer (incongruent). The task was to make a judgment on appropriateness of the target picture. Results found a contextual effect for both the WS group and matched control group, with better performance in the congruent condition, with a slower response latency in the WS group suggesting a possible delay in the development of integrating context information. Although not directly related to individuals with autism, the use of background pictures (scenes) to elicit meaning is similar in methodology to the following study.

Use of prior knowledge in pairing stimuli

The ability to use context relies, in some way, on use of prior knowledge to make meaningful connections between single elements to form a coherent whole (Frith, 1989). Some research has suggested that individuals with ASD do not use prior knowledge (e.g. Frith & Snowling, 1983; Frith & Hermelin 1969, Shah & Frith, 1983). One explanation for this finding in autism may be to do with a difficulty with generalisation, i.e. the idea of *reduced generalisation* put forward by Plaisted (2001), who proposed that the inability to integrate pieces of information is due to an inability to recognise similarities between stimuli and / situations. In line with a difficulty in generalisation, Klinger & Dawson (2001) propose that individuals with autism store each exemplar, rather than extracting prototypes from stimuli in their environment, thus stimuli that are "alike" are more problematic. A task requiring matching similar stimuli might therefore be difficult for individuals with autism.

In comparison, Pring and Hermelin (1993) claimed that there was no difference between individuals with and without ASD in their use of prior knowledge. With a sample of savant artists, the authors tested the differential effect of semantic and structural similarity of pictures on reproduction memory. The participants were shown sets of semantically-linked and structurally-linked pictures. The participants were then asked to reproduce (draw) as many of the pictures as they could recall. Their results found no group difference between the savant (ASD) sample and typical (artistically talented) group. The semantically-linked target stimuli were more likely to be reproduced than the structurally linked target stimuli.

Earlier research by Ameli, Courchesne, Lincoln, Kaufman and Grillon (1988) compared the performance of high functioning autistic (HFA) individuals and TD individuals in a visual recognition memory task. Individuals were presented visually with sets of either meaningful (pictures) or meaningless (nonsense shapes) stimuli, and after a delay had to identify the additional unfamiliar stimulus from the display. The findings revealed that both groups (with and without autism) were able to use meaning to aid memory recognition in the meaningful condition, and both groups were less likely to identify the unfamiliar stimulus in the meaningless set. The results show that individuals with autism are able to utilize prior knowledge and semantic meaning from pictures. In support of these findings, Roper & Mitchell (2001) found that individuals with ASD (with mean age of approximately 19 years old) do use prior knowledge in pairing objects with the appropriate colour. Based on the assumption that individuals with autism experience ‘less capture by meaning’, the authors expected individuals with autism to match stimuli on their surface properties. However, the results showed that individuals with autism paired the stimuli based on the associated stimulus colour, demonstrating that they were able to utilise prior knowledge of the stimuli, comparing the exemplar to the stored image / prototype.

Cross-modal matching of texture in context

This study aims to explore contextual effects on cross-modal matching in autism. Past research has explored these two aspects separately; the effect of context on identification and / pairing, and cross-modal matching respectively. There is only one study (to my knowledge) which has explored contextual effects on cross-modal matching, and this study was conducted with individuals with Williams syndrome (WS; Hsu 2013). There are no studies, to date, that have explored these combined effects in autism.

Previous cross-modal studies in autism, which present conflicting conclusions about the ability of individuals with autism to accurately transfer information cross-modally, have used arbitrary stimuli, i.e. are presented without a context. In comparison, Hsu (2013) explored the *contextual effect* in a visual-auditory cross-modal task, using pictures and auditory target objects. The participants were shown background pictures (photos) of real scenes, followed by an auditory target word, that was either congruent or incongruent with the background picture, e.g. a picture of a kitchen followed by the auditory target object of a microwave (congruent) or a printer (incongruent). Participants were asked to judge the contextual appropriateness of the target.

Results found a significant contextual effect in both individuals with William Syndrome and TD matched groups, with faster response times in the congruent condition. There has been no such study conducted with individuals with autism.

Aims

Study 5, 6 and 7 aimed to explore cross-modal matching of texture and textured shapes in typical and atypical development. The results showed that individuals with autism have difficulty matching texture information cross modally. The following study aims to explore visual-tactile matching of texture in a meaningful context, by doing so creating a less artificial texture context. It is presumed that typically developing individuals demonstrate 'central coherence', which enables the individual to make meaningful connections between semantically related stimuli to create a coherent whole (Happé, 2000). Palmer (1975), working with typically developing individuals, found that appropriate contextual information increased accuracy and confidence in an object identification task. This has been further supported by McCauley, Weil and Sperber (1976) who found that higher associative relatedness of object words produced significantly faster word naming in typically developing children. These examples giving evidence that TD do use context information to understand their environment. In addition, we know that individuals with autism have been found to use context information (e.g. López and Leekam, 2003). Therefore, this study explored whether the cross-modal matching deficit observed in those individuals with autism would still be present using a more realistic texture context. This type of non-verbal contextual information has rarely been explored (e.g. Jolliffe and Baron-Cohen, 2001), and never been used in a visual-tactual cross modal task. By creating a meaningful visual scene, and integrating textures within the scene, the task should help individuals identify the textures more readily. In doing so, this should facilitate matching of the visually presented texture and the haptically explored tactile texture. If texture matching performance improves in the meaningful context, it is expected to result in similar matching performance in both individuals with autism and the matched TD group.

Method

Participants:
A sample of 48 typically developing children (Mean CA = 10.24, age range 8 to 12 years old) were recruited through local schools in the North East of England. Sixteen children with autism (Mean CA = 11.56, age range 9 to 12 years old) were recruited through special needs schools in the North East of England. All children in the ASD group had previously received a clinical diagnosis of autism by experienced clinicians using the guidelines of standard criteria (DSM-IV; American Psychiatric Association, 1994).

Design:
A mixed design was used, with group as the between subject variable, and scene type (texture matching pairs) the within subject variable. The dependent variable was the total number of correctly matched texture pairs, calculated as proportion correct for each picture type.

Materials:
Two picture boards were created (size A3; 42cm length by 29.cm width) with 6 textures incorporated as particular items e.g. a knitted woollen jumper on a farmer. There was one indoor scene of a dining room, and one outdoor scene of a farmer and his dog in a field (refer to figure 4.7. below).

On each picture there were 6 textures. The same textures were used as in Study 5 on cross-modal matching. Three textures were *same* comparison pairs, and 3 were *different* comparison pairs, thus a total of 12 trials. Refer to Table 4.20 below for details of the texture comparison in each trial.

Table 4.20*: Texture comparison pairs for the indoor and outdoor scene, indicating visual and tactile textures used.*

Indoor Picture				**Outdoor Picture**			
Same trials		Different trials		Same trials		Different trials	
Visual	Tactile	Visual	Tactile	Visual	Tactile	Visual	Tactile
wallpaper	wallpaper	wax	rubber	grass	grass	bark	leather
sponge	sponge	cotton	plastic	wood	wood	fur	fleece
Tissue	tissue	velvet	satin	hair	hair	wool	carpet

A wooden box, with windows on either side was used to conceal the tactile texture. The child could place their hand through one end (covered with a soft material curtain) and the experimenter could place the texture in from the opposite side of the box.

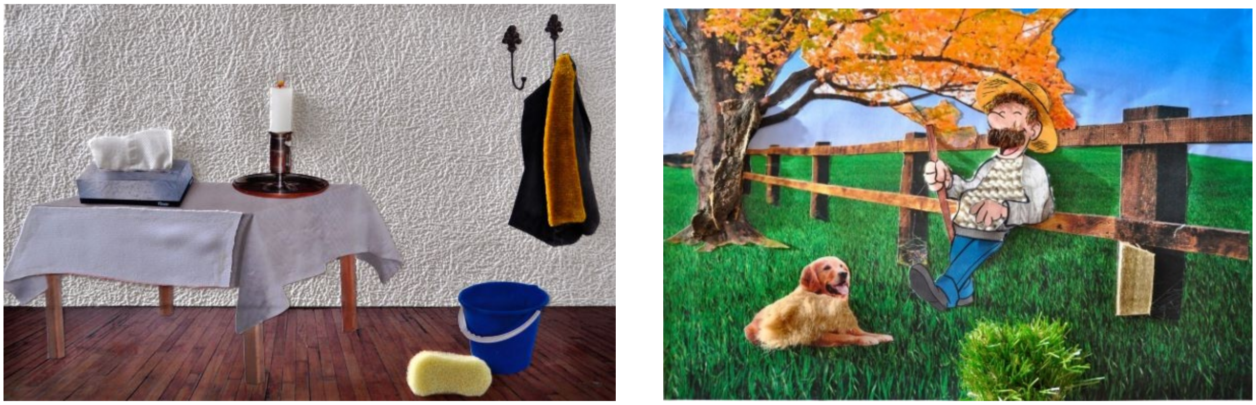

Figure 4.7: *Indoor and outdoor visual scene with integrated textures.*

Procedure

Participants viewed the scenes in a different order to ensure against any order effects. These participants had not previously seen / been exposed to these textures in any of the other studies. The experimenter ensured that the participant fully understood the task and answered any queries the participant had.

The child was asked to place their writing hand into the box. If they were unsure which their writing hand was, the experimenter asked them to write or draw on a piece of paper to ensure they used their dominant hand during the study. Inside the box, they were asked to keep their hand in a loose fist position with their index finger extended. The child was then asked to choose the first texture they wanted to start with on the visual picture. This helped to engage the child in the task. Thereafter, the experimenter chose the next texture.

Once the visual texture had been selected, e.g. wool on the farmer's jumper, the experimenter placed the corresponding texture beneath the box. The experimenter then dragged the texture beneath the child's index finger three times at a rate of approximately 1 stroke per second. This was to control for exposure time on the texture. The experimenter then asked the child "Is the texture the same or is it different?". In rare cases where the child seemed confused, the question was repeated in a slightly different manner with the experimenter pointing to the visual texture and emphasising the comparison to the felt (tactile) texture. The child responded with 'same' or 'different' until all 12 trials were completed.

Data analysis

All data was checked for normality before any analysis was carried out.

Results

Scores represent the proportion of correctly matched texture pairs, for both the indoor and outdoor scene. Refer to Table 4.21 and Table 4.22 for descriptive statistics for unmatched and matched comparisons.

Unmatched sample descriptives

Table 4.21: *Proportion correct for indoor and outdoor scene.*

				Proportion Correct	
Group	N		CA	*IN*	*OUT*
TYP	48	Mean	10.24	.77	.78
		SD	3.80	.15	.17
ASD	16	Mean	11.56	.67	.72
		SD	3.09	.11	.18

Matched sample comparison

Table 4.22: *Sample descriptives for matched groups including proportion correct.*

					Proportion Correct	
Group	N		CA	WISC score	*IN*	*OUT*
TYP	32	Mean	11.14	101.34	.78	.81
		SD	3.76	38.66	.14	.15
ASD	16	Mean	11.56	99.13	.67	.72
		SD	3.09	39.78	.11	.18

Two typically developing children were matched to each child with ASD. Children were matched on their WISC raw score for verbal and non-verbal ability to ± 3 points.

An independent t-test found no group difference for total WISC raw score, t(46) = .178, *p* = .859.

Exploring performance on texture matching in matched samples

A mixed model ANOVA revealed no main effect of scene type (F(1,46) = 1.81, *p* =.185). A significant group effect was found (F(1,46) = 7.72, *p* =.008) with typically developing individuals obtaining a higher score at matching textures (Mean = .797) than the ASD group (Mean =.698). No significant interaction was found between scene and group (F(1,46) =.037, *p* =.848).

4.9 Combining Study 5 and Study 8 to explore whether meaningful context can aid matching.

Creating a meaningful context in Study 8 did not aid visual-tactual matching in autism. In order to further explore the effect of using a meaningful context in visual-tactual matching in autism, Study 5 and Study 8 were compared. Study 5 was the first cross-modal study and used the same texture trials as Study 8.

Participants and Design:

Eleven typical and 11 ASD individuals from Study 5, and 12 typical and 12 ASD individuals from Study 8 were used. These were previously matched on WISC raw score (refer to Tables below). The two factors, Group (TYP; ASD) and Meaning (Meaningful; No Meaningful context) were used. The dependent variable was *total proportion correct*. Proportion correct was calculated across scene type for Study 8.

Table 4.23: *Descriptive statistics for Group - Typical and ASD (standard deviation in brackets).*

Group	N	CA	WISC raw score	Proportion Correct
TYP	23	9.26 (3.03)	86.35 (35.49)	.79 (.07)
ASD	23	10.87 (2.72)	81.78 (32.73)	.68 (.01)

Table 4.24: *Descriptive statistics for Meaningful and No Meaningful context (standard deviation in brackets).*

Meaningful	N	CA	WISC raw score	Proportion Correct
NO	22	9.41 (1.97)	81.91 (27.86)	.72 (.11)
YES	24	10.67 (3.58)	86.04 (39.02)	.74 (.12)

No group differences were found in WISC raw score for both Group comparison (TYP and ASD; $t(44) = .45$, $p = .65$), nor for Meaning (NO meaningful context and YES meaningful context; $t(44) = -.41$, $p = .68$).

Exploring differences in *total proportion correct*, a 2 x 2 factorial ANOVA found a significant Group effect ($F(1,42) = 13.84$, $p = .001$) with better performance in the typical group compared to the ASD group. No significant effect of Meaning was found ($F(1,42) = .49$, $p = .488$) and no interaction was found between Group and Meaning ($F(1,42) = .72$, $p = .40$). The context did not improve performance for either the typical or ASD group. Therefore, despite the use of a meaningful context visual -tactual texture matching is poor for individuals with autism.

Conclusion

The aim of Study 8 was to explore whether the deficit in matching visual-tactual information in ASD would remain when matching texture in a meaningful context. The results showed the same cross modal matching difficulty as found in the previous studies, with significantly better performance in the TD group, *suggesting that the visual-tactual matching difficulty observed in individuals in autism remains even when matching less artificial texture stimuli.* Poorer matching performance in the ASD group is still observed when comparing Study 5 and Study 7. In addition, Study 7 controlled for exposure time, further evidencing that contact time cannot account for group differences in performance.

4.10 General Discussion

The studies in this chapter aimed to explore whether individuals with autism have difficulty integrating visual – tactile texture information, as a possible explanation to unusual tactile responses observed in atypical development. Study 4 explored visual-tactile matching of fine texture. Despite no significant association found between group and direction of shift with matched samples, the same trend is found in the pattern of results in non-matched and matched sample comparison, with typically developing group being more homogenous whereas the ASD group divided equally between negative and positive shift. The result suggests that something unusual is happening with the visual-tactile matching of texture in individuals with autism. Study 5 explored visual – tactual matching of every day textures, i.e. those textures that we come into contact with daily. Results found that individuals with autism are significantly poorer at matching visual and tactile texture information, compared to typically developing individuals and those with ADHD. When controlling for exposure time in the follow-up study (Study 6) these results were replicated, with better matching in the typically developing individuals than those with autism on *total proportion correct*. Comparing Study 5 and Study 6 together the results indicated that exposure time does not affect accuracy in matching for either the typically developing group and the individuals with autism. There was still a significant group difference in performance, with better matching performance in the typically developing group. When shape and texture are combined in Study 7, performance is worse in the texture block, than in the shape block for both the typically developing and ASD group. No group difference was found in the visual-tactile matching of shape and texture overall. In Study 8 visual-tactual texture matching was explored using less artificial texture stimuli. The visual-tactual matching deficit was still observed in individuals with autism. Meaningful context did not facilitate texture matching in individuals with autism, with performance still less accurate in individuals with autism compared to typically developing individuals. Although this study did not find an effect of context on visual-tactual matching in autism, it is the first study (to my knowledge) to explore the effect of context on cross-modal matching in autism, using a non-verbal conceptual integration task. The overall finding from these studies is a significant group difference in visual-tactile matching of texture across a number of tasks, with less accurate performance in individuals with autism. The question remains what could explain this difficulty in cross-modal matching of texture?

Less accurate performance observed in the younger groups is consistent with other studies, which have shown that only by 8 years old does performance become adult like. For example, Milner and Bryant (1970) tested within and between modality (vision and touch) matching of shape in 5, 6 and 7-year-old children. Results showed an improvement with age across all conditions. Prior to 8-years old visual and haptic integration of spatial information is not optimal, with observed total dominance on vision or touch even when the dominant modality is less accurate for a specific task, i.e. for size discrimination haptic information dominance, but vision dominates for discrimination of orientation, (Gori, Del Viva, Sandini & Burr, 2008). Is this the same for ASD? Cross-modal matching ability does seem to improve (looking at the trend of the results), however, much later than compared to the typical group. With increased ASD sample size (including younger ASD individuals) age differences could have been explored. Future studies could specifically explore developmental trajectories, and further examine the vast individual differences within atypical samples. A more recent study by Petrini, Remark, Smith and Nardini (2014) examined how adults and children differ in how selective their integration of multiple sensory information is. In an auditory spatial discrimination task, the results found that children paid as much attention to the irrelevant visual cue as to the relevant auditory cue. However, this attribution to the irrelevant cue decreased with age. These results indicate that the ability to filter out irrelevant information increases with age. Perhaps individuals with ASD are developmentally delayed in this ability to filter out irrelevant stimuli, contributing to their less accurate matching performance.

In addition, exploring visual-haptic dimensional preference for texture and shape, Gliner, Pick, Pick and Hales (1969), found that children aged both 5 and 8 years old were dominant visually, but haptically younger children (5 years old) were texture dominant, whereas older children (8 years old) were form dominant. However, this age-related texture effect was not later replicated (Siegel &Vance, 1970). In the cross-modal study of texture and shape above (Study 7) there was still a significant effect of stimulus type, with better performance in the shape condition for all age groups. This discrepancy may be explained by differences in stimulus characteristics and whether they have distinctive features, and how these interact with the sensory mode (vision or touch), e.g. a stimulus may be particularly distinctive visually, but not tactilely or visa versa.

Research has shown that infants between the ages of 6 to 10 months-old engage in "examining behaviour" (e.g. Ruff, 1984) which involves intense multisensory attention to single objects. It is through this intensive examination of objects in their environment that help the infant to resolve the issue of correspondence and allow plenty of opportunity to develop a comprehensive repertoire of haptic-visual links. It has been reported that children, later diagnosed with autism, do not engage in object manipulation in the same way as typically developing children (Baranek, 1999). It could be possible that this lack of early object examination in autism may reduce the haptic-visual links, contributing to the difficulty in matching haptic and visual information cross-modally later in development.

Hermelin and O'Connor (1970) were the first to propose that individuals with autism have an impairment in the ability to integrate information. This idea of 'weak central coherence', put forward by Frith (1989), has since been used to address particular behaviours observed in autism, such as hypersensitivity (Heaton, Hudry, Ludlow & Hill, 2008) and fascination with stimuli or detail (Miller, 1999), and may possibly explain poorer cross-modal matching observed in autism, with the inability to integrate multiple pieces of information. There are, however, conflicting results of 'weak central coherence' in autism with visuo-spatial tasks such as Navon Hierarchical Figures Test (e.g. Ozonoff, Strayer, McMahon & Filloux, 1994; Plaisted et al. 2000), and visual illusions (e.g. Ropar & Mitchell, 1999, 2001) indicating no group difference found between autistic and non-autistic individuals in global advantage, or susceptibility to illusions respectively. Given the mixed results and methodological differences, the extent to which WCC can explain this study's findings are limited.

The results support the findings of Jolliffe and Baron-Cohen (2001) showing an impairment in [higher level] conceptual matching. However, the current task relies on facilitation of appropriate context, unlike interference of inappropriate context in Jolliffe and Baron-Cohen's task, where participants were required to make a judgment of appropriateness. Thus, a direct comparison is not possible. A future study could explore the effect of inappropriate and appropriate scenes on (texture) matching.

Use of prior knowledge

There is evidence that individuals with ASD do use prior knowledge in pairing objects by colour (Roper & Mitchell, 2001). Unlike colour, which has very specific associations with stimuli in our environment, e.g. strawberries are red, and grass is green, texture can be very different even with one stimulus. For example, a ball can be smooth and soft, or it can feel hard and rough. Even in nature, green grass can feel soft or firm. Texture is more interchangeable and unpredictable than other stimulus properties. In addition, texture is usually only seen as part of another stimulus, i.e. as the surface property of a more noticeable object stimulus, or as background / foreground information. Therefore, texture may be less likely to be retained as independent of another stimulus or situation. And in this way, cross-modal matching of texture may be more difficult than matching of other object properties, such as shape or size. For example, in the study by Nakano, Kato and Kitazawa (2012) the stimuli were sizable shapes, that could be matched by differences in detail. This is an easier cross-modal task for children with and without autism, compared to visual-tactual matching of texture. Though, when compared to colour matching based on associated semantics (e.g. yellow banana) as in Roper and Mitchell's (2001) study, then one could assume 'fur on a dog' in Study 8 (*Meaningful Texture),* would facilitate recall in the same manner, i.e. by semantic association / relatedness. However, Roper and Mitchell's task was not cross-modal, so there must be caution in making comparisons to the result in Study 8.

An alternative explanation is to consider what can influence our perception. One's schematic knowledge and our experiences influence how we perceive information (Hess & Slaughter, 1990). Wing (1996) suggests that WCC could impair development of one's knowledge base. If individuals with autism are said to have 'weak central coherence', perhaps their ability to store information of surface properties, such as texture, is impaired. This might help explain why some of the participants with autism in this study were unable to [verbally] identify the textures visually or tactually, as their stored repertoire of texture information may by different to typically developing individuals. It has been suggested that individuals with autism have possible memory impairment (Boucher & Warrington, 1976), which may also account for poorer texture matching ability.

Integration of multisensory information

Shah and Frith (1993) proposed that individuals with autism have difficulty integrating information, i.e. using both incoming information (input) and prior knowledge to create a meaningful whole. According to this proposition processing is less 'top-down' and more 'bottom-up'. This idea may help to explain a mismatch of visual and tactile information during the matching task. A mismatch of expectancy might result in confusion or an inability to accurately match texture information. For some individuals this could result in an aversive tactile response (withdrawal / avoidance) and in other individuals could give rise to a fascination with certain texture / tactile stimuli. These behaviours are often exhibited in autism (Tavassoli, Miller, Schoen, Nielsen & Baron-Cohen, 2013). The same could apply to other cross-modal relationships, such as visual -auditory and auditory-tactile, not only visual-tactile.

Future research is needed to explore the extent to which the results are related to the developmental stage, specifically the developmental trajectory of cross-modal matching ability. Sensory difficulties present in early development is autism, may lessen or fade with age. For example, Taylor, Isaac & Milne (2010) measured audio-visual integration with the McGurk Effect in children with and without autism. Initial results found delayed audio-visual integration in the group with autism, but subsequently developed faster audio-visual integration compared to the TD group.

Individuals with autism are hypothesised to have difficulty developing an "averaged" representation of objects in their environment (e.g. Pellicano & Burr, 2012) and therefore see objects and visual stimuli as if for the first time, whereas typical individuals are said to hold schema that enable them to generalise and categorise objects and scenes easily and efficiently. This difficulty is suggested to contribute to the difficulty that individuals with autism have with change and being easily over-stimulated in their environment. According to Ernst (2006) prior experience gives us an idea of what stimulus combinations we can expect to find, and cross-modal coupling is dependent on our prior sensory knowledge about which stimuli 'go together' (coupling prior). If there is an increase in exposure to two previously unrelated signals (properties of a stimulus) / learning that two signals are joint, this would result in a change to the prior knowledge of the joint distribution. Gaining more information about the correlation increases the strength of mapping, and in this way the signals would be integrated. In this way, the reliability of the individuals match between stimuli depends on the strength of their sensory coupling. Therefore the stronger the coupling the higher the probability that two separate unimodal sensory signals, will be integrated into a single multisensory percept. Could it be possible that given individuals with autism experience difficulties in sensory modulation, that there is an increased amount of variability and unpredictability in mapping between signals in the environment, which could result in either weaker mapping (increased mapping uncertainty) or unusual mapping (unusual cross-modal associations)? According to Ernst (2007) weaker coupling results in partial integration and greater conflict between sensory inputs. Is it possible that ASD have weaker coupling regardless of the strength of the probable cross modal mapping due to increased conflict. This could possibly explain why individuals with autism may have difficulty matching visual-haptic texture information. Senkowski, Schneider, Foxe & Engel (2008) suggest that in cross-modal matching, coupled oscillatory activity may link the neural signals across different sensory regions, and thereby may facilitate the degree of similarity between stimulus-related information. This can occur for both uni-modal and multimodal sensory regions. It could possibly be argued that for individuals with autism, oscillatory activity is not coupled which could result in stimulus related information not being matched during cross-modal tasks.

Another possibility is based on the premise that all properties of objects fall into two types; modality specific, for example colour (visual), scent (olfactory) and temperature (touch), and amodal, i.e. properties that are perceived in two modalities (e.g. shape, size and texture). Accordingly, cross-modal memory depends on identifying the amodal properties of the object. The resulting mental representation will also be amodal, and in this way be equally accessible to vision and touch (Bushnell, 1986; Lewkowicz, 1994). Perhaps (as before) individuals with ASD are only able to perceive / focus on a single property and therefore struggle with cross-modal mapping.

The ability of individuals with autism to accurately differentiate texture visually and tactually, further supports the finding that the difficulty solely lies in integrating visual and haptic information simultaneously. Ernst (2007) found that discrimination thresholds of incongruent sensory mapping can be altered through training resulting in previously unrelated sensory signals to be integrated. Future research could perhaps focus on training individuals with autism to map sensory inputs. Repeated exposure to coupled sensory inputs would increase cross-modal mapping, and in turn could help individuals make meaningful sensory connections. Over time, this type of training could possibly go some way to alleviate distress caused by the mismatch of visual-haptic information in the environment.

Chapter five

Summary, discussion and future research

5.1 Summary

This thesis aimed to explore tactile sensitivity in typical and atypical development. Anecdotal reports highlight the negative impact of unusual sensory symptoms for those individuals with autism. Emphasised in the reports is the debilitating consequences of tactile defensiveness, often resulting in avoidance or withdrawal of physical contact with others and their environment. Through a series of studies, this research aimed to gain a better insight into the possible contributing factors of tactile sensitivity in autism. Studies explored texture preference, tactile sensitivity and visual-tactile matching in typically developing individuals and individuals with ASD and ADHD.

Study 1 examined texture preferences and aversions to gather baseline information about texture preferences in typical development and then to make comparisons with atypical groups. A survey was developed to explore texture preferences and aversions of everyday textures that individuals would commonly come into daily contact with. Based on reports of aversion to, avoidance of, or fascination with specific textures, it was expected that texture preferences would be different or extreme preferences or aversions would be evident. Results found that texture preference remains consistent across typical development, with most preferred texture being smooth. This finding is consistent with previous research, with preference linearly related to smoothness (Ekman, Hosman, and Lindstrom, 1965). Contrary to expectation, no group differences in texture preference were found between typically developing individuals and those with autism, and ADHD. Having knowledge of preferences and aversions in individuals with autism and ADHD allows us to better understand what contributes to unusual tactile behaviours. Inclusion of the ADHD group was to compare tactile preference and sensitivity to the ASD group, as it is known that individuals with ADHD have sensory processing difficulties (e.g. Yochman, Parush & Ornoy, 2004). The finding that individuals with ADHD have similar texture preferences and aversions to the ASD and typical group indicates that perhaps the anecdotal reports of unusual texture preferences may not be related to preference per se, but rather to differences in sensory modulation, i.e. negative affect. Information on sensory processing was also obtained using the Sensory Profile questionnaire, to explore differences in patterns of sensory processing between typically developing individuals and those with ASD. As expected, there were clear group differences in sensory processing across the four sensory quadrants; Low Registration, Sensation Seeking, Sensory Sensitivity and Sensation Avoiding. Yet, sensory processing patterns were not found to be related to texture preference.

Study 2 explored preference for texture complexity. Previous research in autism has indicated a difficulty in processing complex visual stimuli (Bertone, Motron, Jelenic & Faubert, 2005). It was predicted that individuals with ASD would show a preference for less complex tactile and visual texture stimuli. In this experiment, children with autism, children with ADHD and typically developing children were asked to indicate their most preferred texture in two conditions; tactile only, and visual only. Textures were previously rated on level of complexity. The two most complex, two least complex and two moderately complex textures were then systematically paired against each other. No significant group difference in preference for visual and tactile complexity was found. Perhaps this is not surprising, as some previous research has found no group difference in complexity preference between typically developing children and children have lower cognitive functioning (Spitz & Hoats, 1961). There was a significant visual preference for complexity in both typical and atypical samples. This result however contradicts both the findings of Spitz and Hoats (1961) who also found that both the typical and atypical group preferred low complex visual stimuli, and the findings of Berlyne and Lawrence (1963) which indicated higher rankings of low complex patterns. However, there is no recent literature to support these findings so cautious interpretation is needed.

The relationship between anxiety, personality and preference for complexity in autism was explored, with the prediction that high anxiety would relate to an aversion to complexity. Harvey and Ware (1967) found that "concreteness" of conceptual functioning disposes an individual toward a low tolerance of dissonance. Individuals with autism have been suggested to be 'concrete' in their thinking, unable to be flexible in thought (Hobson, 2012; Grandin, 1995), and therefore would expect a lower tolerance of cognitive dissonance in autism, and thus lower tolerance for stimuli that evoke increased level of arousal. Contrary to predictions there were no group differences, and no significant relationship was found between level of anxiety and preference for complexity. It has also previously been found that individuals who score high on extraversion prefer more complex stimuli (e.g. Bartol & Martin, 1974; Christensen, 1962). No such relationship was found in typically developing individuals nor those with autism. Therefore, the issue of personality and anxiety was not considered further in this thesis.

In chapter three, tactile sensitivity of fine texture was examined. It was expected that individuals with ASD would have enhanced tactile sensitivity, as enhanced discrimination has previously been shown in ASD in vision and audition. The Enhanced Perceptual Discrimination theory (O'Riordan, Plaisted, Driver, Baron-Cohen, 2001; O'Riordan & Passetti, 2006) proposes that individuals with autism have heightened sensitivity to detail and thus have enhanced discrimination. The question remained whether *enhanced discrimination* would result in over-sensitivity to certain stimuli, and thus more accurate fine texture discrimination.
In this experiment individuals were asked to haptically explore fine texture with vision occluded. Texture was fine sandpaper, grouped into Easy, Medium and Hard discrimination conditions based on the average difference in particle size between each comparison pair. No significant group difference was found in fine texture discrimination between individuals with ASD and typically developing individuals. Ward et al. (2017) suggest that perhaps the heightened sensitivity observed in autism may be specific to certain types of stimuli in all modalities, based on a frequency of sound and / or vibration. Perhaps, since all texture used in the study were fine grit, there was no advantage of heightened sensitivity in the discrimination task.

Since no group differences were found in either texture preference nor texture discrimination, the studies in the next chapter explored cross-modal matching of texture. Study 4 examined visual-tactile matching of fine texture. In this cross-modal study, we wanted to explore whether there was a difference in the perceived roughness of texture. It was predicted that individuals with ASD may perceive texture as being rougher than it actually is, compared to typically developing individuals. That is, perhaps heightened sensitivity in autism would result in textures being perceived as rougher than they are in fact. The task was to feel a texture and then to visually decide on a match from a series of textures ranging from smooth to coarse. Despite expectations, there was no significant group difference in 'distance from target stimuli', suggesting no difference in perceived roughness. Study 5 then explored visual-tactile matching of texture. In this study, everyday textures were used to explore visual-tactual matching in ASD. It was predicted that individuals with ASD might have difficulty matching visual-tactile texture information cross-modally. The theory of Sensory Integration (Ayres, 1972; discussed in Chapter

1) proposed that individuals with sensory processing difficulties may have difficulty integrating multiple sensory input, which in turn affects behavioural response. In addition, it was suggested that individuals with ASD may not store a repertoire of texture information and therefore there would be a mismatch of information between the visual and tactile information. Our perception of incoming stimuli is affected by our prior experience. It has been proposed that knowledge is not attenuated by previous experience in autism, and therefore they may perceive the world as more accurate than others (Pellicano & Burr, 2012; discussed in Chapter 4). Pellicano and Burr's (2012) suggestion of 'hypo-priors' in autism may contribute to the unusual tactile aversive or seeking behaviours observed in some individuals with autism, if tactile stimuli is perceived as new and unexpected. It was predicted that individuals with autism would perform worse in the visual- tactual matching task than typically developing individuals. The task was to match visually presented texture with a tactual texture in a same-or-different task. Results found significant group differences with individuals with ASD preforming worse at visual-tactual matching than typically developing individuals and individuals with ADHD. The study concluded that there seems to be a mismatch of expectation in individuals with ASD which may help explain why some individuals with ASD react negatively to tactile stimulation. A future study could explore the idea of *hypo-priors* by allowing participants to manually explore the textures prior to the cross-modal task. If individuals with autism can retain this tactile texture information, we would expect more accurate cross-modal matching. A follow-up study (Study 6), controlling for exposure (contact with the texture) revealed the same pattern of results with *total proportion correct*, with typically developing individuals being more accurate in visual-tactile matching than individuals with autism.

Visual-tactile matching of shape and texture was then explored in Study 7. As noted previously, Nakano, Kato and Kitazawa (2011) reported better cross transfer of shape for individuals with autism compared to controls. In this study it was expected that individuals with ASD would be able to successfully match shape cross-modally but would be poorer at texture matching. For matched samples, a main effect of stimuli type was found with more accurate performance in the *shape* block than in the *texture* block. A significant group difference was found with *total proportion correct*, with more accurate visual-tactual matching in typically developing individuals compared to individuals with autism. However, using a more sensitive measure of discrimination, this group difference disappeared. This may be due to the small number of trials in the task, and correcting for perfect scores (previously discussed).

Results partially confirm the prediction, supporting the conclusion that texture information may be problematic for individuals with ASD. As the materials in Study 7 were textures presented in an artificial way, i.e. out of everyday context, Study 8 explored texture matching in a meaningful context. In this study, we explored the idea that giving texture a context would improve visual-tactile matching in ASD. Everyday textures were presented within a visual scene, and individuals were asked to match the visual textures to haptically presented textures. A significant group difference was found, with more accurate texture matching in the typically developing individuals. It was concluded that giving texture a meaningful context does not remove the disadvantage of visual-tactual matching in ASD. In this study, exposure duration was controlled, further suggesting that these results and those of Study 4 are not due to differences in time spent exploring the texture.

Previous studies in Occupational Therapy use assessments with passive prodding to assess tactile defensiveness (e.g. Southern California Sensory Integration Test, SCSIT, Ayres, 1972). However, parent reports state an avoidance of active exploration in those children later diagnosed with sensory processing difficulties (Larsen, 1982). Given the importance of active exploration within the environment for typical development (Gibson, 1962; Piaget, 1953), studies in this thesis focussed on active exploration. However, self-produced tactile stimulus is perceived as being less ticklish than when the stimulus is generated externally. Using fMRI Blakemore, Wolpert & Frith (1998) explored neural responses to tactile stimuli and found more activity in the somatosensory cortex when the stimulus was externally produced. Active control of tactile exploration may therefore reduce tactile sensitivity. This may explain why no differences were found in active tactile exploration between typically developing individuals and those individuals with ASD. It may also explain why individuals with ASD did not exhibit tactile defensiveness in the studies presented in the thesis, even though their sensory profiles indicated hyper-responsivity.

Perceiving a texture is a multimodal experience. Not only can one see the surface of a textured object, but also haptically exploring it can result in hearing the sound of the texture. Research has therefore examined the visual-haptic equivalence of texture (e.g. Picard, 2006). Some studies have concluded that touch dominates texture perception, while others have argued that vision is the dominant modality in texture perception (Ernst & Banks 2002; Heller, 1992). In contrast, Guest and Spence (2003) argued that vision and touch contribute independent information on roughness, and by combining these two sources of information results in a division of attention and thereby reduces discriminatory ability. So perhaps less accurate cross-modal matching by individuals with ASD observed during the visual-tactile matching task, could be explained by a difficulty switching attention to and from the visual texture and haptic texture stimulus. Typical infants and young children find it difficult to shift attention away from the most salient feature / dimension (e.g. Bushnell, Shaw & Strauss, 1985). It is also known that individuals with autism have difficulty shifting attention (Belmonte, 2000). Reed and McCarthy (2011) found that children with autism (aged 9-13 years old) have difficulty in cross-modal attention- switching between visual and auditory tasks compared to the matched control group, which supports the attentional-shift difficulty in autism. Perhaps during the cross-modal tasks, either the tactile or visual stimulus was more salient for individuals with autism resulting in a difficulty shifting attention between the stimuli to be able to form a unitary percept during matching of the tactile and visual stimulus.

There is evidence from patients with right-hemisphere lesions who show impaired integration of single elements on traditional tests, and exhibit related social and pragmatic deficits akin to those found in autism (Fitz et al., 1992; Nadler et al., 1996). This may explain the poorer performance in cross-modal matching observed in the studies in Chapter 4. The suggestion of difficulty integrating the visual-tactual stimuli also supports Frith's (1989) suggestion that a difficulty integrating information may be a core deficit in autism.

5.2 Limitations

Despite matched sample sizes of ASD and ADHD individuals being small, they are comparable to other similar study designs exploring sensory differences and / tactile sensitivity. More trials in each task may have increased the likelihood of finding significant group differences in fine texture discrimination, however young children and those with ASD or ADHD would not have been able to complete the tasks if took any longer. A future study could go in and test on multiple days. Nevertheless, this may be impractical for schools and result in task fatigue for children. Ideally sample sizes would have been bigger with a larger matched sample to increase statistical power. However, despite the small samples, significant group differences were found in a number of the studies presented in this thesis.

The findings show that despite sensory symptoms, as portrayed on different sensory profiles individuals do not exhibit such unusual sensory behaviours during the tasks. For example, individuals in these studies were able to explore all the textures without exhibiting an aversive / emotive response. Perhaps the tasks used here are either not sensitive to or not related to the specific symptoms usually displayed by the individual. An alternative measure of tactile defensiveness may have added additional information about hypo- and hyper-responsivity, such as the Sensory Over-Responsivity Scale (Schoen, Miller & Green, 2008). The most commonly used assessment measures to assess tactile defensiveness have been developed by Occupational Therapists (OT) and can only be used by qualified OT's trained to use these measures, e.g. the Southern California Sensory Integration Test (SCSIT; Ayres, 1972). The SCSIT relies on passive prodding on the individual to record tactile responses. For the purposes of this research the focus was on active exploration, with literature to support the lack of engagement with objects in the environment in individuals with sensory processing difficulties. As a measure of sensory processing, the Sensory Profile was used to ensure that individuals with autism in this research has significantly different sensory profiles from the typically developing individuals. The Sensory Profile has been used in the literature to positively identify tactile defensiveness (Dunn, 1998), so is a valid measure to use.

Women with ASD are reported to have more sensory issues than men with ASD (Lai et al. 2011). However, the ASD samples in this thesis were primarily male, except for the TPAQ study, where no gender differences were found in texture preference in typical and atypical development. Future studies should explore possible gender differences in tactile sensitivity.

In addition, there is research to suggest sensory symptoms decrease with age (Crane, Goddard & Pring, 2009). It would be valuable to explore how tactile sensitivity changes with increasing age. The results from the TPAQ showed significant age effects in texture preference in the typical sample, but no such age differences were found in individuals with autism. It would be interesting to explore age differences in texture discrimination and visual-tactual matching in atypical development. Research has shown that sensory symptoms remain throughout development (Crane, Goddard & Pring, 2009), but there is no research specifically focussed on the developmental trajectory of unusual tactile processing.

Considering syndrome heterogeneity, prevalence rates of sensory difficulties in individuals with autism vary substantially from 100% to approximately 30% (e.g. Greenspan & Wieder, 1997;

Volkmar, Cohen & Paul, 1986; Baranek, Foster & Berkson, 1997; Leekam et al., 2007). It is therefore possible that the samples included in this thesis may not be representative of individuals who exhibit tactile defensiveness. Future studies could include more measures of tactile responsivity, (e.g. Bauer, 1977; High, Gough, Wright, & Fitch, 1998) to more carefully explore tactile sensitivity. Sensory processing difficulties in individuals with autism are also known to be changeable, with hyper-and hypo- responsivity varying across sensory modalities (Dunn, 1997; Miller, Robinson, & Moulton, 2004). This provides a further challenge to researchers as there is much individual variability in sensory difficulties in autism. Although conclusions are drawn from comparing matched samples, given the heterogeneity of sensory symptoms in autism, it is valuable to explore differences in tactile sensitivity within the ASD samples, despite having small sample size. The studies in this thesis comparing ASD and ADHD samples also provide some evidence that the sensory difficulties exhibited in cross-modal matching are syndrome specific to autism.

5.3 Future direction

The thesis aimed to explore tactile sensitivity in typical and atypical development, with a specific focus on ASD and comparison to ADHD. Touch is essential for typical development, as emphasised in the introduction, but the question remains what affect would tactile deprivation have on the developmental trajectory? We also know that early tactile contact in infancy forms the foundation in the development of social and communication skills, as discussed in Chapter 1. There is a vast amount of evidence for unusual tactile processing in ASD (e.g. Cascio, 2010; Tavassoli, et al. 2016), but what we do not know is how these differences in response to tactile stimuli affect communication skills and cognitive development in individuals with autism. Foss-Feig, Heacock and Cascio (2012) explored the relationship between sensory responsivity and autistic features. They found a significant positive correlation between tactile hypo-responsivity and social and communication impairment, but hyper-responsivity did not correlate to any core features of autism. This would suggest that tactile under responsivity (lack of tactile exploration) has significant implications for social development.

Future research should explore tactile responsivity and social impairment longitudinally, exploring links between core symptoms of ASD, sensory symptoms and the core social and communication deficits in autism. For example, Foss-Feig, Heacock and Cacsio (2012) examined the relationship between unusual tactile processing and the core symptoms of autism. The authors found that tactile hypo-responsiveness was significantly related to increased social and communication impairments. This relationship could be explored longitudinally to further understand the impact that unusual tactile processing and sensory symptoms have on social and communication development.

Determining specific preferred or aversive (avoided) textures may be beneficial for designing tools and possibly toys that would encourage exploration from early development. However, there is a vast amount of individual variability in sensory issues, so it is important to understand tactile differences at an individual level. Despite no significant reported differences in texture preference in the TPAQ results and no group differences in tactile sensitivity, there is evidence of differences in neurological response to texture between typical and ASD groups (Cascio et al., 2012). Taking the viewpoint that sensory processing difficulties in one modality can affect the development of other sensory modalities (Röder, Rösler, Spence, 2004) and can cause or contribute to later developmental problems, early remediation of tactile defensiveness could help reduce possible developmental difficulties that may be associated with unusual tactile sensitivity.

The advantage of focussing on a single modality has allowed a more detailed examination of tactile processing differences in typical and atypical development, which might not have been observed if collapsing across sensory modalities. In doing so, has yielded new information about tactile sensitivity in atypical development, specifically ASD and ADHD.

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APPENDIX A

Tactile Preference and Aversion Questionnaire

Caregiver Questionnaire

Has your child been diagnosed with any of the following (please tick as appropriate):

Autistic Spectrum ☐ ADD/ADHD ☐ Learning Disabilities (please specify) ____________
Tactile Defensiveness ☐ Suspected Autism ☐ Other (please specify) ____________

Name of Child: ____________ Male ☐ Female ☐

Child's date of birth: ____________

Please indicate on the scale below to what extent your child likes to feel the following materials. Indicate by circling, (1= Like very much, 3 = Neutral to the feel of that material, and 5 = Dislike very much). If your child has not come into contact with the material, or you do not know how your child reacts towards a particular item please tick the DON'T KNOW box:

	LIKE VERY MUCH	LIKE SOMEWHAT	NEUTRAL	DISLIKE SOMEWHAT	DISLIKE VERY MUCH	
1. WOOL (e.g. a woollen jumper)	1	2	3	4	5	DON'T KNOW ☐
2. SILK (e.g. silk scarf)	1	2	3	4	5	DON'T KNOW ☐
3. FUR (e.g. animal fur)	1	2	3	4	5	DON'T KNOW ☐
4. WOOD (e.g. wooden table top)	1	2	3	4	5	DON'T KNOW ☐
5. HAIR (e.g. stroking hair on arm / head)	1	2	3	4	5	DON'T KNOW ☐
6. VELVET	1	2	3	4	5	DON'T KNOW ☐
7. TISSUES	1	2	3	4	5	DON'T KNOW ☐
8. RUBBER (e.g. rubber door mat)	1	2	3	4	5	DON'T KNOW ☐
9. FLEECE	1	2	3	4	5	DON'T KNOW ☐

	LIKE VERY MUCH	LIKE SOMEWHAT	NEUTRAL	DISLIKE SOMEWHAT	DISLIKE VERY MUCH	
10. PLAY-DOUGH	1	2	3	4	5	DON'T KNOW ☐
11 a) SAND on feet (e.g. sand box)	1	2	3	4	5	DON'T KNOW ☐
11 b) SAND on hands (e.g. sand box)	1	2	3	4	5	DON'T KNOW ☐
12. SKIN (e.g. stroking arm / leg)	1	2	3	4	5	DON'T KNOW ☐
13 a) SMOOTH PLASTIC (e.g. table surface)	1	2	3	4	5	DON'T KNOW ☐
13 b) ROUGH PLASTIC (e.g. studs on a Lego brick)	1	2	3	4	5	DON'T KNOW ☐
14. TIGHTS (e.g. stroking tights on legs)	1	2	3	4	5	DON'T KNOW ☐
15. STICKY SURFACE (e.g. glue on hands)	1	2	3	4	5	DON'T KNOW ☐
16 a) CARPET on feet (e.g. barefoot on carpet)	1	2	3	4	5	DON'T KNOW ☐
16. b) CARPET on hands (e.g. stroking carpet)	1	2	3	4	5	DON'T KNOW ☐
17. SPONGE	1	2	3	4	5	DON'T KNOW ☐
18. COTTON (e.g. cotton T-shirt)	1	2	3	4	5	DON'T KNOW ☐
19 a) SANDPAPER (fine)	1	2	3	4	5	DON'T KNOW ☐
19 b)SANDPAPER (course)	1	2	3	4	5	DON'T KNOW ☐
20. PAINT (e.g. finger painting)	1	2	3	4	5	DON'T KNOW ☐
21. LACE (e.g. lace table cloth)	1	2	3	4	5	DON'T KNOW ☐

	LIKE VERY MUCH	LIKE SOMEWHAT	NEUTRAL	DISLIKE SOMEWHAT	DISLIKE VERY MUCH	
22. TREE BARK	1	2	3	4	5	DON'T KNOW ☐
23. LEATHER	1	2	3	4	5	DON'T KNOW ☐
24. MARBLE (e.g. floor / kitchen surface)	1	2	3	4	5	DON'T KNOW ☐
25. WAX (e.g. crayons)	1	2	3	4	5	DON'T KNOW ☐
26 a) GRASS on feet	1	2	3	4	5	DON'T KNOW ☐
26 b) GRASS on hands	1	2	3	4	5	DON'T KNOW ☐

Please state any other materials not listed, indicating whether they are extreme preferences or aversions.

THANK-YOU FOR TAKING THE TIME TO FILL OUT THE QUESTIONNAIRE.

APPENDIX B

Tactile Sensitivity Study: BLOCKS of trials

Different trials	*Same trials*
Block one: EASY LEVEL	
60 – 180	80 - 80
80 – 320	180 – 180
100 – 400	320-320
(REPEATED TWICE)	
Block two: MEDIUM LEVEL	
60 – 100	80 - 80
100 – 180	180 - 180
180 – 320	320 - 320
(REPEATED TWICE)	
Block three: HARD LEVEL	
60 – 80	80 – 80
120 – 180	180 - 180
320 – 400	320 – 320
(REPEATED TWICE)	