TOWARDS AN UNDERSTANDING OF THE ROLE OF ASSOCIATIVE LEARNING IN RISK FOR MENTAL HEALTH PROBLEMS.

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Michaelmas Term 2012

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Experimental Psychology in the Department of Experimental Psychology at the University of Oxford.

Word Count: 63, 100

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ABSTRACT

The ability to prioritize information enables us to think and take action without being overwhelmed by external stimuli or internal thoughts and feelings. Neuroticism is associated with altered processing of emotional information but differences in the processing of emotional information may arise from basic differences in information processing, such as altered processes of attention, changes in sensitivity to salient information, or differences in the ability to encode conjunctions of information. Through this thesis, I explore the relationship between neuroticism and processing of non-emotional information, with a particular focus on learning about combinations of information.

Associative learning paradigms were used to test ability to learn about combinations of information and neuroticism was observed to be associated with strong non-linear discrimination learning. The tendency to focus on specific details was associated with weak non-linear discrimination learning. A novel model of associative learning is presented, offering an account for how variation in the ability to engage in non-linear discrimination learning might be understood.

Mechanisms underlying the association between neuroticism and strong non-linear discrimination learning were explored. Neuroticism was not found to be associated with a tendency to focus on specific details or shifts in attention towards goal relevant information. Neuroticism was not found to be associated with enhanced ability to identify feature conjunctions, altered sensitivity to the relative validity of stimuli or pre-exposure of stimuli.

The importance of understanding individual differences in processes of associative and the value of associative learning tasks to look at information processing biases underlying neuroticism are discussed.

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CHAPTER 1

1 INTRODUCTION

In 1999 an unarmed West African immigrant with no criminal record was shot and killed by four New York police officers outside his home on Wheeler Avenue in the Bronx. The police thought Amadou Diallo was armed and dangerous. Multiple factors that, if attended to and pieced together, would have indicated Amadou was harmless and frightened by the police. The officers failed to combine relevant information, focusing instead on two factors; Amadou ran from them and appeared to pull a weapon from his trousers. The weapon was in fact his wallet (Gladwell, 2005).

This was a highly stressful event for the police officers. The experience of stress has many effects upon the body and brain. Adrenaline, released in response to stress (Cullinan, Herman, Helmreich, & Watson, 1995) is associated with strengthened memory of emotional events (Cahill & McGaugh, 1998). This effect is thought to be mediated by activation of β-adrenergic activity within the amygdala, an area of the brain involved in emotion processing (Cahill, 2000; Cahill & McGaugh, 1998). Prolonged exposure to stress is associated with an increase in cortisol release (Cullinan et al., 1995). The hippocampus plays a major homeostatic function regulating cortisol release and is thus highly sensitive to stress (Sapolsky, 1996). In animals, high levels of glucocorticoids, released in response to stress, have been observed to cause hippocampal damage (Fuchs & Flugge, 2003; Gould & Tanapat, 1999; Magarinos, McEwen, Flugge, & Fuchs, 1996; Woolley, Gould, & McEwen, 1990). As such, it is thought that while stress may facilitate the activity of the amygdala, increasing the perceived emotional valance of information processed, it may inhibit processes of the hippocampus (Cahill & McGaugh, 1998).

Though the traditional view of the hippocampus concentrated on specialisation for spatial memory (Morris, Garrud, Rawlins, & Okeefe, 1982), contemporary theories propose a role in the rapid encoding of sensory information to guide current behaviour (Bast, 2007). As such, the hippocampus is thought to be vital for binding semantic and episodic information (Eichenbaum, 2000). It may be argued that it was this process of rapidly integrating stored knowledge with sensory information to guide behaviour that the New York police officers failed to engage when they mistakenly assumed Amadou Diallo was armed and dangerous.

There is a considerable body of research to suggest that stress acutely influences encoding and later recall of information, enhancing focus on specific details at the cost of integration with peripheral information (Brown, 2003; Cavenett & Nixon, 2006; Loftus, 1979; Loftus, Loftus, & Messo, 1987). The effects of stress upon the hippocampus are, however, in general, reported to occur in response to chronic stress (Fuchs & Flugge, 2003; Gould & Tanapat, 1999; Magarinos et al., 1996). As such, information processing biases may be expected in individuals with high baseline stress levels. The personality trait, neuroticism is associated with increased reactivity to stressors (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Gunthert, Cohen, &

Armeli, 1999; Mroczek & Almeida, 2004; Suls & Martin, 2005) and high levels of distress (Engelhard, van den Hout, & Lommen, 2009). Therefore neuroticism may be expected to be associated with reduced performance on tasks requiring binding of multiple stimuli to mediate task performance.

This thesis considers the possibility of an association between neuroticism and impairments on tasks requiring binding of information. It also addresses the broader issue of individual differences in the ability to combine separate pieces of information together and treat that combination as distinct and different from constituent units of information. I address whether shifts in attention, between focusing on specific details or the global picture, influences such ability. This thesis addresses whether dispositional factors, such as personality, might have influenced the ability of the police officers in the Bronx to rapidly combine information to identify that Amadou Diallo was not a threat.

1.1 INTRODUCTION TO ASSOCIATIVE LEARNING

The research presented in this thesis addresses individual differences in human associative learning and considers whether differences in ability to learn about configurations of stimuli relate to psychopathology. This introduction starts with a brief overview of research demonstrating that exploration of mechanisms of associative learning has, to date, provided a valuable contribution to our understanding of psychopathology. The introduction the continues to address more general research on individual differences in human tendency to learn about separate elements or configurations of presented stimuli, before providing an overview to element and configural models of learning.

1.1.1 LEARNING, SALIENCE AND PSYCHOPATHOLOGY

Associative learning provides a practical and valuable framework to explore individual differences in the ability to bind stimuli into distinct configurations. Associative learning theorists understand behaviour by studying how associations between stimulus representations are acquired and used. Such studies have considered how the intensity and salience of stimuli influences learning (Logan, 1954; Perkins, 1953; Redhead & Pearce, 1995b), how our attention shifts between different stimuli to influence learning (de Wit & Dickinson, 2009; Harris & Livesey, 2010; Le Pelley & McLaren, 2004; Lubow, 2010; Mackintosh, 1975; Mclaren, Wills, & Graham, 2010; Pearce & Hall, 1980) and how experience changes the way we acquire new associations (Kamin, 1968; Lubow, Schnur, & Rifkin, 1976; Seligman, 1972).

At the simplest level, associative learning is concerned with the process by which animals, including humans, learn to associate a particular stimulus (the conditioned stimulus; CS) with an outcome (the unconditioned stimulus; UCS) such that the subject expects the outcome to occur when the stimulus is presented. The acquisition of this association may occur if the stimulus is repeatedly paired with the outcome. Acquisition is assumed to be asymptotic (Rescorla & Wagner, 1972), that is to say the rate of learning is fastest when the pairing is novel; repeated pairings of the stimulus and outcome allow a gradual increase in the associative strength of the stimulus until the associative strength of the stimulus reaches the maximal strength that the outcome can support. This process of learning is captured by Equation 1.

Equation 1

$$\Delta \mathrm{V} = \alpha\,(\lambda - \mathrm{V})$$

Where V is the associative strength of the stimulus – outcome association and λ is the magnitude of associative strength that the outcome can support. α is the salience of the stimulus. Change in associative strength (ΔV) depends upon the difference between the maximal associative strength that can be supported by the outcome (λ) and the existing associative strength (V). As this difference is largest at the outset of conditioning, the rate of learning decreases incrementally as the associative strength increases.

Several factors that influence ability to acquire associations should be highlighted. The perceived intensity of the outcome will influence the associative strength that can be supported (λ). For instance, learning that a certain stimulus signals food may occur more rapidly if the food is highly desirable, i.e., chocolate or if there is more of it, i.e., four pieces of chocolate rather than two (Wagner, Siegel, Thomas, & Ellison, 1964). Internal drive will also influence λ, for instance, the outcome, chocolate, is more likely to support learning if the learner is hungry (Pavlov, 1927, p32; Mackintosh, 1974, p71).

The intensity or salience of the stimulus (α) will also influence learning, with increases in intensity or salience supporting stronger learning (Kamin & Brimer, 1963; Kamin & Schaub, 1963). When multiple stimuli are presented simultaneously, learning will occur preferentially with the most salient stimulus, while less salient stimuli may be overshadowed (Pavlov, 1927, p 141; Mackintosh, 1971). The salience of the stimulus, however, is not necessarily fixed, but may change with experience (Le Pelley & McLaren, 2004; Le Pelley, Turnbull, Reimers, & Knipe, 2010; Mackintosh, 1975; Pearce & Hall, 1980; Pearce & Mackintosh, 2010). For instance stimulus salience will decline if the stimulus is presented repeatedly in the absence of an outcome (Lubow, 2010; Lubow, Markman, & Allen, 1968; Lubow & Moore, 1959).

Given the fundamental influence that stimulus salience has upon learning, variation in what individuals find salient should have a substantial impact upon the acquisition of associations. For instance, individuals with depression and individuals at risk of depression tend to find negative information more salient than non-depressed individuals (Bradley, Mogg, & Lee, 1997; Chan, Goodwin, & Harmer, 2007; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Matthews, Pitcaithly, & Mann, 1995; Mogg, Bradley, & Williams, 1995; Phillips, Hine, & Thorsteinsson, 2010; Rusting, 1998, 1999). Simply applying basic rules of learning theory, this may be expected to have an impact upon the associations learned. Salient stimuli will overshadow less salient stimuli (Mackintosh, 1971); therefore if individuals at risk of depression find negative information more salient, they may be more likely to learn about the associations between negative stimuli and paired outcomes as opposed to associating positive or more neutral stimuli with paired outcomes. The tendency to find negative information more salient may also increase the perceived intensity of negative outcomes, allowing these outcomes to support stronger acquisition of associative strength. This would, for instance, result in individuals at risk of depression forming stronger associations between stimuli and negative outcomes. This would be expected to have a detrimental impact upon subsequent expectations and behaviour.

Individuals do not only differ in terms of what they find salient but vary in how they perceive and process salience. For instance, the dsyregulated hyperdopaminergic state, characteristic of schizophrenia, is thought to lead to aberrant assignment of salience, resulting in delusions as the patient attempts to make sense of the aberrant associations (Kapur, 2003). Schizophrenia is associated with a diminished ability to shift attention away from irrelevant information, making individuals with schizophrenia more susceptible to an overload of information processing (Solomon et al., 1981; Weiner, Lubow, & Feldon, 1981, 1984). This inability to shift attention can be observed when looking at latent inhibition. Latent inhibition occurs when a stimulus is repeatedly presented in the absence of an outcome. One argument suggests that this reduces the salience of the stimulus, impairing ability to learn about the stimulus (Lubow, 1989, 2010; Lubow et al., 1976). Latent inhibition is impaired in acute but not chronic schizophrenia (Baruch, Hemsley, & Gray, 1988; Gal et al., 2009; Gray, Pilowsky, Gray, & Kerwin, 1995; Rascle et al., 2001; Vaitl & Lipp, 1997).

Dysregulation of attention can also be identified in blocking tasks (Haselgrove & Evans, 2010). The standard blocking effect occurs when prior training with one stimulus interferes with the acquisition of associative strength with a second stimulus, when it is presented in compound with the initial stimulus (Kamin, 1968, 1969). For instance if **A**+ is trained prior to training **AX**+, the associative strength acquired by **X** is reduced compared to a control. This effect occurs because **A** in the **AX** compound predicts the outcome, prohibiting further learning with **X** (Kamin, 1968, 1969). Blocking is disrupted in acute (Jones, Gray, & Hemsley, 1992b; Jones, Hemsley, Ball, & Serra, 1997) and non-paranoid schizophrenia (Moran, Al-Uzri, Watson, & Reveley, 2003; Oades, Rao, Bender, Sartory, & Muller, 2000) and disrupted blocking is associated with negative and depressive symptoms in particular (Moran, Owen, Crookes, Al-Uzri, & Reveley, 2008).

Individuals also differ in their sensitivity to changes in the value of an outcome stimulus. For instance, drug dependency is associated with impaired sensitivity to changes in the value of an outcome. Unlimited experience of an unconditioned stimulus should result in satiation. For instance, given unlimited access to eat chocolate a point of satiation should be reached where the consumer no longer wishes to consume chocolate. Satiation usually impairs a stimulus's capacity to support learning and the stimulus is said to be devalued. Following devaluation people are usually less likely to engage in behaviour previously rewarded by the devalued outcome (Hogarth, 2011; Hogarth, Chase, & Baess, 2012). Individuals with high levels of impulsivity, however, are less sensitive to outcome devaluation. While they will report a decline in the hedonic appraisal of the devalued outcome, they are more likely to continue choosing this outcome (Hogarth, 2011; Hogarth et al., 2012). Vulnerabilities to drug dependency may thus be mediated by individual differences in sensitivity to changes in the value of an outcome stimulus (Hogarth & Chase, 2012).

Why do individuals vary in sensitivity to outcome devaluation? Insensitivity to devaluation may occur because behaviour has become habitual. We usually learn to engage in a given behaviour in the presence of a certain stimulus to elicit reward. This is a stimulus → response → outcome chain. With repeated execution of this chain of events, the outcome may become redundant and the stimulus may elicit a response independent from the value of the outcome (de Wit & Dickinson, 2009; Hogarth & Chase, 2012). It is possible that the speed with which a stimulus response association is established, or the strength of this association, may vary between individuals.

Considering individual differences in sensitivity to stimuli and associated outcomes has also developed our understanding of contingency learning. Learning contingencies allows people to make judgements about how accurately events and actions predict subsequent outcomes, allowing behaviour to be guided by experience (Baker, Murphy, Vallee-Tourangeau, & Mehta, 2001). For instance, bad economic news often precedes a fall in stock price. Experience of this contingency may prompt people to sell investments in response to bad economic news in anticipation of a fall in stock price. While we regularly experience positive contingencies, where the probability of an outcome occurring increases in the presence of a stimulus, we also experience zero contingencies where the outcome is no more likely to occur in the presence than the absence of a stimulus. We are not always accurate at identifying zero contingencies, especially when asked to consider whether our actions cause an outcome (Baker, Msetfi, Hanley, & Murphy, 2010). While a general tendency to overestimate the contingency between action and outcome has been reported, Alloy and Abramson (1979) suggested that depressed individuals were more accurate at judging that they had no control over an outcome. Further exploration has, however, revealed some interesting effects which do not support the original findings.

As the density of the outcome increases, judgements of action-outcome contingency tend to increase in non-depressed individuals despite the actual contingency remaining unchanged (Msetfi, Murphy, Simpson, & Kornbrot, 2005; Vallee-Tourangeau, Murphy, & Baker, 2005). Non-depressed individuals are also influenced by the gap between trials, the inter-trial interval (ITI). The ITI is by default experience of a no-action-no-outcome contingency because no-action can be executed during the ITI and nothing happens. In a high density condition, where the outcome occurs on 75% of trials, incorporating the experience of the ITI will influence contingency judgement. In a zero contingency design, where the outcome occurs on 75% of the trials in which participants make an action but also occurs on 75% of the trials in which participants make no action, incorporating the ITI into judgements of contingency will substantially increase the experience of no-action-no-outcome, weakening the contingency between no-action and outcome (Msetfi et al., 2005). As such, it is reasonable to judge the action-outcome contingency as above zero especially if ITI periods are long (Baker et al., 2010; Msetfi, Murphy, & Simpson, 2007; Msetfi et al., 2005). This pattern of contingency judgements is observed in non-depressed, but not depressed individuals, suggesting that rather than being more accurate judges of zero contingency, depressed individuals may simply be less sensitive to the information presented during an ITI (Baker et al., 2010; Msetfi et al., 2005).

This research has advanced understanding of information processing biases associated with psychopathology. The research conducted into the associative learning mechanisms underlying psychopathology does not simply inform us about what happens when processes of associative learning break down. All of the effects discussed above occur along a continuum, indicating substantial individual difference in associative learning. Though schizophrenia is a serious mental health problem occurring with a prevalence of around 0.4% (McGrath, Saha, Chant, & Welham, 2008; Saha, Chant, Welham, & McGrath, 2005), schizotypy, a dimension reflecting traits of schizophrenia, varies across the population (Mason & Claridge, 2006; Mason, Linney, & Claridge, 2005). Schizotypy is, like schizophrenia, associated with disruptions in latent inhibition and blocking (Haselgrove & Evans, 2010; Moran et al., 2003) as well as impaired conditional task performance (Haddon et al., 2011) and impaired visual context processing (Uhlhaas & Silverstein, 2005; Uhlhaas, Silverstein, Phillips, & Lovell, 2004). Similarly, while only a subset of the population will develop drug dependency (Anthony, Warner, & Kessler, 1994; Donny & Dierker, 2007; Gill, 2002; Grant et al., 2004; Hughes, Helzer, & Lindberg, 2006; Hyland, Rezaishiraz, Bauer, Giovino, & Cummings, 2005), impulsivity, associated with variation in sensitivity to outcome devaluation procedures (Hogarth, 2011; Hogarth et al., 2012), varies across the population. Finally, the contingency research that has been conducted, has observed effects in students with low BDI scores (dysphoria; Msetfi, Murphy, Kornbrot, & Simpson, 2009; Msetfi et al., 2007; Msetfi et al., 2005). Thus from clinically focused research alone, there is evidence of considerable individual difference in processes of associative learning.

1.1.2 INDIVIDUAL DIFFERENCES IN HUMAN ASSOCIATIVE LEARNING

Research into individual differences across the population has contributed to better understanding of everything from academic achievement to crime and delinquency, from income and poverty to health (Lubinski, 2000). There has, however, been relatively limited interest in individual differences in processes of associative learning. Recently, however, several studies have identified individual differences in explicit and linear associative tasks (Kaufman, DeYoung, Gray, Brown, & Mackintosh, 2009; Williams & Pearlberg, 2006) and these differences have been found to contribute to variance in intelligence, independently from the contribution of working memory and processing speed (Kaufman et al., 2009; Tamez, Myerson, & Hale, 2008; Williams & Pearlberg, 2006). These studies tested basic ability to learn and remember a linear stimulus-outcome association, where a given stimulus was consistently paired with an outcome. In both of the tasks used (a three term contingency learning task and a paired-associate learning task) participants learnt the associations between words.

Kaufman et al., (2010) have also identified individual differences in implicit learning. Implicit learning allows us to detect complex and noisy regularities in our environment and is typically characterised by a set of automatic, associative, non-conscious and unintentional learning processes (Kaufman et al., 2010). Implicit learning was measured using a probabilistic serial reaction time task. Kaufman et al., (2010) found implicit learning to be associated with: verbal reasoning, measured using the verbal reasoning subsection of the Differential Aptitudes Test; processing speed, as assessed through a composite score from tests assessing verbal seeped, numerical speed and figural speed; and self-reported openness, measured using the NEO-PI-R (Costa & Mccrae, 1995).

Against this backdrop of research into individual differences, non-linear learning appears somewhat neglected. Linear learning refers to the acquisition and use of associations between separate stimuli and outcomes. In contrast non-linear learning refers to learning about compound stimuli as distinct configurations, associated with different outcomes from those associated with the compound's constituent stimuli. Despite considerable efforts to understand why and how external factors influence ability to learn about combinations of stimuli as configurations distinct from their constituent stimuli (Melchers, Shanks, & Lachnit, 2008), few studies have considered whether individuals differ in their ability to combine stimuli and learn about distinct combinations of stimuli. Ability to learn that combinations of stimuli have a different meaning to their constituent stimuli is a fundamental aspect of cognition, allowing flexibility in information processing. At the extreme, a break down in the ability to learn about distinct combinations of stimuli may result in memory disturbances such as those seen in PTSD where single features evoke associated memories in the absence of contextualising information (Brewin & Holmes, 2003).

1.1.3 GENERALISATION AND NON-LINEAR LEARNING.

A fundamental requirement of any theory of learning is the need to account for and specify how behaviour might be elicited by a stimulus that has never previously been encountered. Apart from basic processes related to non-specific arousal that might underlie an overt response to a new stimulus or innate tendencies or sensitivities to particular stimuli, behaviour is often guided by learning from previous experience. One mechanism that allows previous experience to influence behaviour in new situations is generalisation of associative strength. Generalisation of associative strength facilitates transfer of acquired associations between new and old events on the basis of stimulus similarity (Bush & Mosteller, 1951; McLaren & Mackintosh, 2002; Pearce, 1987; Rescorla, 1976; Rescorla & Furrow, 1977).

Similarity has been quantified as the proportion of features that stimuli share in common. On this basis, generalisation should be facilitated to the extent that stimuli share a greater proportion of common features (Kruschke, 1992; Mackintosh, 1975; Mcclelland & Rumelhart, 1985; Nosofsky, 1984; Pearce, 1987; Rescorla & Wagner, 1972; Vanhamme & Wasserman, 1994). Since, in principle every stimulus, like all snowflakes, is unique, experienced stimuli are widely assumed to be subdivided into multiple features or elements (Brandon, Vogel, & Wagner, 2000; McLaren & Mackintosh, 2000; Rescorla, 1973). For instance, a red square may be subdivided into features reflecting hue, brightness, shape and size. Ability to predict responding to a novel stimulus or event may depend on the extent to which the stimulus or event shares features in common with previously experienced stimuli or events.

Models of learning, using similarity to predict generalisation of associative strength have, however, taken different perspectives on the relationship between compounds and their constituent stimuli and as such make different predictions regarding the generalisation of associative strength to novel stimulus presentations. If two stimuli have been associated with a particular outcome (i.e., **A**+, **B**+), there is more than one prediction that can be made regarding the outcome expected following the co-occurrence of the stimuli (i.e., **AB**). One approach linearly sums the outcome associated with each separate stimulus and predicts that double the outcome should be expected following the compound (i.e., **AB**++; Rescorla & Wagner, 1972). Others argue that outcome expectation following a compound should be governed by the compound's similarity to previously experienced stimuli. Pearce (1987, 1994) has suggested that as the **AB** compound is 50% similar to **A** and 50% similar to **B**, expectation of the outcome occurring following the compound **AB** should be 50% of that following **A** plus 50% of that following **B**. Experimental findings support both models, suggesting variability in the perception of similarity and processes of generalisation (Melchers et al., 2008).

There has been considerable work exploring the influence that external factors such as stimulus modality have upon generalisation of associative strength (Kehoe, Horne, Horne, & Macrae, 1994; Lachnit, 1988; Myers, Vogel, Shin, & Wagner, 2001; Rescorla & Coldwell, 1995) and several explanations have been developed (Melchers et al., 2008). For instance, the outcome expected following a compound may be less than the linear sum of the outcomes associated with the separate constituent stimuli when perceptual interaction or masking causes the separate stimuli to be perceived differently in a compound than when they are presented alone (Honey & Hall, 1989; Myers et al., 2001; Rescorla & Coldwell, 1995). These effects influence uni-sensory combinations of stimuli to a greater extent than multisensory combinations (Melchers et al., 2008). Even within the same modality stimuli can also be processed differently depending on whether they vary on separable or integral dimensions. While separable dimensions, such as shape, combine such that distinct components are perceptible, integral dimensions, such as hue, combine to form holistic units (Garner, 1970, 1974). Lachnit (1988) demonstrated that these dimensions influenced learning, such that separable dimensions encouraged learning about separate stimuli while learning with integral dimensions encouraged learning about distinct configurations. As such expectation of an outcome following a compound may be less when integral dimensions are combined.

This research allows us, to an extent, to predict how generalisation of associative strength will occur given the stimuli used. It has provided a framework to understand how ability to combine stimuli and treat combinations of stimuli as distinct and different from constituent stimuli changes as external factors, such as stimulus properties, change. Linear relationships between separate stimuli and the co-occurrence of these stimuli are more likely to be observed when multimodal stimuli are used and when stimuli vary along separable dimensions. In contrast to this research far less attention has been devoted to the influence of internal variables such as disposition or experience.

The studies that have been conducted to date, exploring individual differences in tendency to learn about separate stimuli as opposed to the distinct configurations they compose, suggest variation may be mediated by working memory capacity (Juslin, Olsson, & Olsson, 2003; Shanks & Darby, 1998; Wills, Graham, Koh, McLaren, & Rolland, 2011). Shanks and Darby (1998) demonstrated that ability to learn about combinations of stimuli was associated with later use of rule as opposed to feature-based generalisation (Shanks & Darby, 1998). Rule-based generalisation depends on the abstraction of and generalisation from a rule. Feature-based generalisation depends upon the surface similarity between separate stimuli and compounds. As such, it is assumed that rule-based generalisation is more complex and might require greater understanding of the discrimination (Shanks & Darby, 1998) or more working memory capacity (Wills et al., 2011).

In the Shanks and Darby (1998) experiment participants were trained on a negative patterning discrimination (i.e., **A**+, **B**+, **AB**-) intermixed with trials where separate stimuli were paired with the outcome (i.e., **I**+, **J**+) before being asked for a prediction of the outcome following the co-occurrence of the separately trained stimuli (i.e., **IJ**?). Some participants expected the outcome to occur following the **IJ** compound, showing featured based generalisation. Others demonstrated application of a negative patterning rule, expecting no outcome to occur following the **IJ** compound. Rule-based generalisation was associated with strong initial discrimination learning (Shanks & Darby, 1998). Wills et al., (2011) found a similar distinction; individuals who completed a concurrent task while learning the initial discrimination were more likely to show feature-based generalisation (Wills et al., 2011). As such, it may be that greater working memory capacity is associated with stronger non-linear discrimination learning and rule-based generalisation. The direction of causality here is unclear.

Working memory and basic processes of associative learning have been identified as recruiting different neural substrates; dorsolateral areas of the prefrontal cortex in the case of working memory (Petrides, 1995, 2000) and more posterior frontal regions in the case of associative learning (Petrides, Alivisatos, Evans, & Meyer, 1993). Separate neural correlates do not preclude the possibility that variation in working memory underlies variation in the ability to learn about distinct configurations of stimuli. However, as larger working memory capacity is associated with stronger learning in general (Kyllonen & Stephens, 1990), increased working capacity memory may be expected to be associated with general and uniform changes in learning as opposed to systematic variation in tendency to treat combinations of stimuli (i.e., **AB**) as distinct and different from their constituent stimuli (i.e., **A** or **B**).

Individual differences in the ability, or tendency, to learn about configurations, distinct from their constituent stimuli have implications for models of associative learning. Two approaches to modelling associative learning have been developed; to differentiate between these two approaches simplistically, elemental models account for learning about separate stimuli while configural models account for learning about distinct configurations. Though many modifications have been made to the two models so that they can both, to an extent, account for learning about separate stimuli and learning about distinct configurations, these modifications may be better suited to explaining how external factors, such as stimulus dimension, produce flexibility in learning, than accounting for the effects of human individual differences.

The discussion below considers the elemental and configural approaches to modelling learning and briefly reviews the modifications that have been made to allow these models to account for flexibility in learning.

1.1.4 ELEMENTAL MODELS

Elemental models (i.e., Rescorla & Wagner, 1972) assume that each stimulus is processed separately and develops its own associative link with the outcome. In dealing with compound stimuli the elemental approach continues to assume that each individual stimulus develops its own associative link to the outcome. As such the associative strength of a compound stimulus (i.e., **AB**) is calculated as the algebraic sum of the associative strength of each of the stimuli present (i.e., Vab = Va + Vb).

Forty years have passed since the development of the Rescorla-Wager model and with time many changes have been made to this elemental approach. As discussed above, if two stimuli have been associated with a particular outcome (i.e., **A**+, **B**+) there is more than one prediction that can be made regarding the outcome expected following the co-occurrence of the stimuli (i.e., **AB**). Elemental theory naturally accounts for situations where the outcome following the co-occurrence of the stimuli is double that following the separate constituent stimuli. Elemental theory has, however, faced a fundamental problem in accounting for situations where the associative strength of a compound is not the algebraic sum of the associative strength of the composite elements.

Elemental theory needs to be able to account for ability to learn that a compound stimulus can become associated with a different outcome to that associated with its constituent stimuli. This kind of problem is called a non-linear discrimination. If it is the case that generalisation occurs on the basis of similarity then something that is 100% similar to something else should elicit the same response. However, in non-liner discriminations the opposite occurs. Non-linear problems require participants to learn that combinations of stimuli may be associated with outcomes independently from the outcome associated with their constituent stimuli. Non-linear discriminations can be contrasted to linear discriminations which depend only on the one-to-one correspondence between separate stimuli and the associated outcome. A range of approaches have been adopted to allow the elemental model of learning to account for non-linear discrimination. Strategies include marking the compound as different such that it is assumed to have properties distinct from its constituent elements (Rescorla, Grau, & Durlach, 1985) or accepting that factors such as perceptual interaction (Rescorla & Coldwell, 1995) or masking (Myers et al., 2001) mediate perceptual differences between individual stimuli and compounds.

1.1.4.1 MODIFYING ELEMENTAL MODELS

PERCEPTUAL HYPOTHESES

Perceptual hypotheses assume that a compound stimulus may be treated as distinct from its constituent stimuli because the representation of stimuli presented in compound interact either by fusing into a single representation (Baker, 1972; Razran, 1965, 1971; Young & Pearce, 1984), contributing to a distinctive joint signal (Heinemann & Chase, 1975; Kehoe & Gormezano, 1980, pp. 370 – 373), or modifying the representation of each other (Honey & Hall, 1989; Hull, 1943, 1945; Myers et al., 2001; Rescorla & Coldwell, 1995). These hypotheses argue that transfer of associative strength between a compound and its constituent stimuli will be imperfect because the representation of the compound is qualitatively different from the representation of the constituent stimuli.

THE UNIQUE CUE MODIFICATIONS

One way to allow elemental theory to account for participants' ability to learn that a compound is associated with a different outcome to its constituent stimuli is to assume that the presentation of multiple stimuli activates some unit or representation not activated by the separate stimuli. Rescorla proposed that the stimulus compound may consist of separate elements directly reflecting the elements composing the separate stimuli, plus an element unique to that specific combination of stimuli (Rescorla, 1973; Rescorla & Wagner, 1972). This unique element is referred to as a unique cue.

How would such a unique cue work? Some arguments suggest that the unique cue emerges out of an interaction between stimuli (Hull, 1943; Razran, 1939, 1971). For instance, Hull suggested that the unique cue is a product of afferent neural interaction, produced by the co-activation of individual stimuli (Hull, 1943). In contrast, Rescorla has argued that the unique cue is a rule-based solution which exists independently from emergent perceptual interaction (Rescorla, 1973; Rescorla et al., 1985).

To address this argument, Rescorla et al. (1985) tested whether non-linear discrimination could be transferred to novel stimuli. This is the same kind of question addressed in the Shanks and Darby (1998) study into rule and feature-based generalisation. Pigeons were initially trained with a specific non-linear problem, a negative patterning discrimination (**A**+, **B**+, **AB**-). Following training with the negative pattering discrimination, pigeons received four sessions of second-order conditioning, in which X was followed by A and Y was followed by B.

To solve the negative patterning discrimination on the basis of perception, pigeons would have to distinguish between the sensory properties of the same stimuli presented individually and in compound. If pigeons discriminated on the basis of sensory properties, then learning with the **AB** compound should not transfer to a novel compound with different sensory properties (i.e., **XY**). If, however, the negative patterning discrimination is solved through the formation of a unique cue present when representations of **A** and **B** are jointly activated, substituting **X** for **A** and **Y** for **B** should allow transfer of learning, because the **XY** representation should associatively evoke representation of stimulus **A** and stimulus **B**. As such the presentation of **XY** should activate the unique cue representation previously elicited by the joint activation of **A** and **B**. This experimental design is shown in Table 1.

Table 1: Experimental design used by Rescorla et al., 1985 to test the rule-based account of a unique cue.

Phase 1	Phase 2		Test
A+	**X**: **A**	**Y**: **B**	**XY**?
B+			
AB-	**X**: **A**	**Y**: **C**	
C+			
AC+			

Rescorla found that responding to **XY** following paring of **X** and **Y** with **A** and **C** (condition 2) was significantly higher than following paring with **A** and **B** (condition 1). Responding to **XY** in condition 1 was lower than responding to the elements **X** and **Y**, as would be expected following a negative patterning design. While Rescorla used the results of this experiment to argue that the unique cue acts like a rule, it is important to note that **A**, **B** and **C** had different associative histories. A more convincing demonstration of a unique cue acting as a rule may have been to include **D**+, **E**+ and **DE**- in the initial training. If the unique cue functioned as a rule elicited by the joint activation of the two stimuli trained in compound, then pairing **X**:**A** and **Y**:**D** should result in a higher responding to **XY** at test than if **X**:**A** and **Y**:**B** had been paired, because although all the stimuli would have had the same associative histories, associatively evoking the representation of **A** and **D** should not activate a unique cue representation.

COMMON CUES

At the same time as Rescorla introduced the notion of a unique cue, he was ready to accept the concept of common cues, (i.e., Rescorla et al., 1985). The notion of common cues assumes that all stimuli consist of many elements and between similar stimuli there may be common elements. As mentioned above, many theories of associative learning have adopted the assumption that stimuli are composed of multiple elements, reflecting different properties of a stimulus (Blough, 1975; Brandon et al., 2000; McLaren & Mackintosh, 2000, 2002). Rescorla suggested that it is intuitively reasonable that a degree of overlap between similar stimuli, such as high and low tones, should exist, facilitating generalisation of associative strength between the stimuli. The extent to which this generalisation occurs should be dependent upon the salience of the shared elements (Rescorla, 1976). This is an early instantiation of McLaren and Mackintosh’s (2000, 2002) concept of multiple overlapping elements.

REPLACED ELEMENTS

If we are to assume that all stimuli share some information in common, why stop at the relatively inflexible approach of having a single common element? The Replaced Elements Model (REM; Brandon et al., 2000) builds on the earlier idea of stimuli being composed of many elements (e.g., Blough, 1972). The model conceives of stimuli as represented by multiple features or elements, focusing on common elements and how these elements interact with unique elements. In representing a compound there are assumed to be context independent elements which are activated whenever the stimulus is presented and context dependent elements which are activated or inhibited depending on the combinations of stimuli presented (Brandon et al., 2000). For instance, when stimulus **A** is presented alone, representations of the elements $\mathbf{A}_1$ and $\mathbf{A}_2$ may be activated. When stimulus **A** is presented in combination with stimulus **B**, the element $\mathbf{A}_2$ may be replaced by a new element, $\mathbf{A}_3$. The model adopts the stipulation that a compound should have no more capacity to elicit associative strength than any of its constituent elements. As such, in adding and inhibiting elements, the change made to the elements represented is qualitative, with the elements represented being changed, rather than a quantitative.

The replacement parameter ‘r’ allows flexibility in the proportion of context dependent elements replaced when stimuli are presented in compound (Wagner, 2003). When “r = 0,” no replacement occurs and as such strong generalisation of associative strength between stimuli and compounds is predicted. When “r = 1” there is considerable replacement of elements, and as such the generalisation predicted to occur between compounds and constituent stimuli should be reduced. With maximal replacement of elements, the representation of the compound should be distinct from the representation of the separate stimuli, facilitating non-linear learning. This flexibility is based on the premise of varying ability to discriminate or differentiate separate stimuli from the configurations in which they might be presented. The replacement parameter goes someway to reflecting the necessity to incorporate flexibility, but to date a comprehensive method for calculating the parameters stipulating variation in replacement of elements has not been developed.

MULTIPLE OVERLAPPING ELEMENTS

McLaren and Mackintosh (2000, 2002) extended the concept of replaced elements to describe situations in which all stimuli are composed of multiple elements (McLaren & Mackintosh, 2000, 2002). Following stimulus sampling theory (Estes, 1950) they assume that only a subset of elements will be activated by the presentation of a given stimulus. Stimulus sampling theory postulates that only a subset of the elements that might potentially be activated by the presentation of a given stimulus will actually be sampled on any given trial (Estes, 1955). Rather than there being a one-to-one correspondence between a presented stimulus and the representation formed, stimuli representations consist of patterns of graded activation distributed over a set of units corresponding to elements of the stimuli. This allows for substantial flexibility.

In this model, McLaren and Mackintosh (2000, 2002) treat similarity as a case of overlapping elements. The more similar stimuli are the more elements overlap. Each representational unit is postulated to have a tuning curve, responding most strongly to one particular value on the dimension and less strongly to neighbouring values. The strength to which an element is activated is thus not the linear sum of input strength but a function relating to input activation strength following a sigmoid curve, characteristic of Gaussian distribution. This allows the model considerable flexibility predicting responding to stimuli and stimuli compounds. For instance, it allows for elements that may be weakly activated when an individual stimulus is presented and be strongly activated when a compound is presented. As such the model incorporates the notion that presenting stimuli in compound can alter the information that is represented.

1.1.5 THE CONFIGURAL APPROACH

Do the changes made to elemental models of learning go far enough? Or are they complex approaches for capturing a simple problem? Pearce's model (Pearce, 1987, 1994) of stimulus generalisation, a modern instantiation of configural theory, takes this approach. In a similar vein to the Replaced Elements Model (Brandon et al., 2000), which would be presented 10 years after Pearce's configural model, Pearce (1987, 1994) links his ideas back to the Hullian perspective that presenting a stimulus compound alters the internal representation that might be produced if only a single stimulus were presented (Hull, 1945).

Configural theory assumes that conditioning results in the formation of a unitary or configural representation of the pattern of stimulation on a given trial. This representation in its entirety can then enter into an association with the outcome (Estes, 1986, 1988; Kruschke, 1992; Nosofsky, 1986; Pearce, 1987, 1994). As the pattern of stimulation changes, it activates previously formed representations to the extent that the new pattern is similar to the previous pattern. Such similarity is calculated as the proportion of elements shared in common as described in Equation 2.

Equation 2

$$jS_A = \frac{Pcom}{P\sum_J} \times \frac{Pcom}{P\sum_a}$$

Where the value of $Pcom$ is determined by the perceived intensity (p) of the stimuli that are common between presented configurations. The values of $P\sum_J$ and $P\sum_a$ are set according to the total perceived intensity of the stimulation on trials where **A** and J, respectively, are presented.

This model assumes that the amount of information attended to and included in a configural representation is limited. As such the model contains a “buffer of limited capacity that is always full and represents the environment or overall pattern of stimulation” currently exposed (Pearce, 1987). Stimuli presented will excite a particular pattern in the buffer. Changing the stimuli will alter the distribution of elements activated in the buffer so that the greater the change in stimuli, the fewer common elements activated. Following the assumption of generalisation on the basis of similarity, configural theory predicts that the associative strength of an untrained compound will be the average of the associative strengths of its constituent stimuli as given in Equation 3.

Equation 3

$$V_{ab} = (V_a \times 0.5) + (V_b \times 0.5))$$

While configural theory assumes that conditioning will result in associations forming between the unitary configural representation and the outcome, the constituent elements remain important. The model represents individual elements. In the connectionist conception of this model, these elements act as nodes which connect to a hidden layer; the configural unit (Pearce, 1994). This in turn forms a connection with the output layer of the model, the outcome (Pearce, 1994). The representation of individual elements becomes important when considering how generalisation occurs. As similarity between configurations is computed on the basis of the proportion of elements that configurations share in common, calculating generalisation depends upon representation of elements (Pearce, 1987, 1994).

The concept of distinct configurations is intrinsic to this model. By assuming that learning involves configurations, the model naturally accounts for capacity to learn non-linear problems (Pearce, 2002; Pearce & Wilson, 1990; Redhead & Pearce, 1995a). The model does not intrinsically allow for instances when combinations of stimuli are not treated as distinct configurations. Summation is one such example. Summation occurs when generalisation of associative strength from separate stimuli to compounds is complete, such that the associative strength of the compound is greater than that of the separate constituent stimuli.

1.1.6 SUMMARY

Both models of learning are well supported with experimental evidence and both models have been modified to allow them to go some way to accounting for the full range of experimental findings. Much of the focus for explaining variation in performance has centred upon the sensory or perceptual properties of stimuli used. In addition to modifying elemental and configural models to allow them to account for flexibility, several models have taken a two system approach, assuming that both elemental learning (associations forming between separate stimuli and outcomes) and configural learning (associations forming between distinct configurations and outcomes) occur (Fanselow, 1999; Rudy & Sutherland, 1995; Schmajuk & Dicarlo, 1992; Schmajuk, Lamoureux, & Holland, 1998). There has been some evidence suggesting dissociated neural correlates of a two system approach, with the hippocampus mediating configural learning (Fanselow, 1999). If chronic stress affects hippocampal function, it may influence engagement in configural learning and ability to learn about distinct combinations of information.

Despite the fact that processing combinations of information as distinct from the constituent information is something human's do and rely upon many times a day, little attention has been devoted to understanding whether ability to learn about distinct configurations varies between individuals. Individual differences in this ability may reflect a basic variation in the flexibility of learning opposed to variation in fundamental capacity to learn. There is an important distinction between being able to learn multiple linear relationships and ability to learn a single association between a distinct configuration of stimuli. We know that individuals differ both in ability to engage in linear (Kaufman et al., 2009; Tamez et al., 2008; Williams & Pearlberg, 2006) and non-linear learning (Shanks & Darby, 1998) but do not know what mechanisms underlie variation in non-linear learning. The experiments presented here look at individual differences in capacity to engage in non-linear learning and attempt to understand mechanisms underlying individual differences. The findings of these experiments have been used to consider how existing models of associative learning might account for the flexibility observed.

1.2 COGNITIVE PROCESSING IN NEUROTICISM

The research presented in this thesis focuses on neuroticism and depression, considering whether neuroticism is associated with changes in tendency to learn about separate elements or whole configural units. This section of the introduction outlines research to date exploring cognitive factors associated with neuroticism.

The ability to prioritize information enables us to think and take action without being overwhelmed by external stimuli or internal thoughts and feelings (Mather & Sutherland, 2011). We attend to, learn about, remember and respond to salient details in our environment. This bias towards relevant information is especially apparent in situations of high emotional arousal or stress, where memory for salient details is enhanced at the cost of peripheral details (Brown, 2003; Burke, Heuer, & Reisberg, 1992; Christianson, Loftus, Hoffman, & Loftus, 1991; Loftus et al., 1987). Arousal is also thought to change our ability to bind information, enhancing within-object binding. This enhances memory of intrinsic features of an object, but not memory for associations between items (Kensinger, 2009; Mather, 2007). Enhanced binding may not be limited to features of single items; Mather and Sutherland (2011) contend that arousal can enhance memory of associations between separate items if the association between the two items has a high priority. As such, arousal may be expected to influence ability to learn about combinations of stimuli. This would be expected to influence non-linear learning.

Experience of stressful situations contributes to the likelihood of developing depression (Hammen, 2005; Monroe & Reid, 2009). Differences in the way information is processed during stressful experiences may be one factor contributing to this relationship. There is, however, enigma in the relationship between stress and depression. Though stressful experiences have the potential to influence the onset of depression, the majority of individuals experiencing stress do not develop depression (Cohen, Janicki-Deverts, & Miller, 2007; Segerstrom & Miller, 2004). Personality traits, particularly neuroticism, predict depression (Kendler & Gardner, 2011; Lahey, 2009) and the interaction between stressful experience and neuroticism may be informative.

Neuroticism has been associated with increased reactivity to stressors (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Gunthert et al., 1999; Mroczek & Almeida, 2004; Suls & Martin, 2005) and high levels of distress (Engelhard et al., 2009). Neuroticism has been associated with a tendency to create more stressful life experiences, as individuals with higher levels of neuroticism tend to react poorly to challenges in their environment (Uliaszek et al., 2010). Given the relationship between neuroticism, stress and memory encoding, it is of interest to understand more about the way individuals with high levels of neuroticism encode, remember and learn about information in non-stressful environments. This may contribute to our understanding of why neuroticism is a risk factor for depression. As neuroticism is associated with chronic high levels of stress, neuroticism may be expected to be associated with changes in the ability to combine stimuli and learn about distinct configurations.

Before looking directly at the relationship between neuroticism and specific aspects of ability to bind, encode and learn about combinations of information, I briefly review current literature on information processing associated with neuroticism.

1.2.1 WHAT DOES IT MEAN TO BE NEUROTIC?

The continuum between emotional stability and neuroticism is one of the Big Five domains of personality (Costa & Mccrae, 1995; Digman & Takemoto-Chock, 1981; Fiske, 1949). The personality trait reflects inability to cope (Mccrae & Costa, 1994), negative emotionality, difficulty regulating emotion (Eysenck & Eysenck, 1967), a tendency to worry (Widiger, Hurt, Frances, Clarkin, & Gilmore, 1984) and experience negative affect when faced with minor stressors (Barnhofer & Chittka, 2010). Interest in the relationship between personality and mental health is not a recent phenomenon (Clark & Watson, 1999; Freud, 1953; Maher & Maher, 1994; Pavlov, 1927), however, since the emergence of a consensus taxonomy of personality there has been considerable research into this relationship (Clark & Watson, 1991; Kotov, Gamez, Schmidt, & Watson, 2010; Malouff, Thorsteinsson, Rooke, & Schutte, 2007; Malouff, Thorsteinsson, & Schutte, 2005; Ruiz, Pincus, & Schinka, 2008).

A meta-analysis of the associations between the Big Three and Five personality traits (i.e., neuroticism, extraversion, disinhibition, conscientiousness, agreeableness and openness) and specific depressive, anxiety and substance use disorders in adults, led Kotov et al., (2010) to conclude that neuroticism is crucial for understanding mental health problems. In particular, neuroticism is a behavioural phenotype associated with mood disorders and risk for first onset and recurrent depression (Clayton, Ernst, & Angst, 1994; Duggan, Sham, Lee, Minne, & Murray, 1995; Kendler, Kuhn, & Prescott, 2004; Roberts & Kendler, 1999; Saklofske, Kelly, & Janzen, 1995; Schmitz, Kugler, & Rollnik, 2003; Scott, Williams, Brittlebank, & Ferrier, 1995). High neuroticism scores are found in individuals with a history of depression (Duggan et al., 1995) and are predictive of future recurrence of depression (Berlanga, Heinze, Torres, Apiquian, & Caballero, 1999).

Despite the strong relationship between neuroticism and mental health problems, researchers have yet to agree on how this relationship should be understood. At least three different perspectives on the relationship have been adopted (Clark, Watson, & Mineka, 1994). Vulnerability models propose that personality has a causal effect on the onset and maintenance of mental health problems (e.g., Boyce, Parker, Barnett, Cooney, & Smith, 1991). Continuity models (e.g., Hirschfeld & Klerman, 1979) contend that personality and mental health problems reflect the same underlying process and as such mental health problems are the extreme of normal personality. Alternatively, mental health problems can be seen to affect personality, as argued in the scar or complication model (e.g., Akiskal, Hirschfeld, & Yerevanian, 1983).

Given the range of models that have been developed to reflect the relationship between personality and mental health, it is perhaps unsurprising that researchers have questioned the value of neuroticism in helping us understand risk for mental health problems. Ormel et al., (2004) have argued that the relationship between neuroticism and mental health problems has been artificially inflated because of the overlap between neuroticism and measures of anxiety and depression. For instance, the neuroticism subscale developed by Costa and McCrae (1995) measures 6 facets; anxiety, angry hostility, depression, self-consciousness, impulsivity and vulnerability. As such the measure of neuroticism must reflect a tendency towards anxiety and depression. Though others contend that the overlapping factors between neuroticism and depression do not account for much of the relationship (Uliaszek et al., 2009), questions regarding the independent value of neuroticism will remain until a clear mechanism specifying how and why neuroticism contributes to risk for mental health problems is established. For neuroticism to add value to our understanding of mental health problems, we need to understand what it means to be neurotic.

It should be possible to move towards an understanding of a personality trait, such as neuroticism, along three separate and inter-related levels, exploring the genetic, neural and information processing base. This brief review concentrates on possible mechanisms contributing to high neuroticism levels, emphasizing information processing biases in particular.

Traditionally neuroticism has been seen as a stable trait associated with alterations in information processing (i.e., Rusting, 1998). Mathews (2012) suggested that it may be just as plausible for the relationship between neuroticism and information processing to function in the opposite direction; how we encode information may influence our personality. For instance, recent studies have demonstrated that information processing training can influence emotional responding; practice attending to positive information enhances positive emotional response to later experiences of success (Grafton, Ang, & MacLeod, 2012) and practice generating imagery of positive outcomes to ambiguous events reduces depressed mood (Lang, Blackwell, Harmer, Davison, & Holmes, 2012). These studies suggest that it is possible that neuroticism, as measured by personality questionnaires, is the product of how individuals process information (Mathews, 2012). This has interesting implications for understanding the relationship between neuroticism and mental health problems; shifting the focus to differences in information processing as the fundamental risk factor for mental health problems.

1.2.2 A ROLE FOR INFORMATION PROCESSING IN UNDERSTANDING THE GENETIC AND NEURAL BASIS OF NEUROTICISM?

Understanding the information processing biases associated with neuroticism may be fundamental to developing an understanding of a genetic or neural basis of neuroticism. Neuroticism is highly heritable, with 50% of variance in neuroticism believed to be of genetic origin (Carey, 2003; DiLalla & Gottesman, 2004; Plomin, DeFries, McClearn, & McGuffin, 2008). Understanding the genetic basis of neuroticism is not simple. Complex traits such as neuroticism are likely to be influenced by multiple genes of small effect rather than a single gene of large effect (Canli, 2008). Even hunting for multiple genes of small effect, very few candidates have been identified. For instance, Lesch et al., (1996) reported an association between neuroticism and a polymorphism modulating synaptic availability of serotonin. The 5-HTTLPR gene codes for the molecule that removes serotonin from extracellular space between nerve cells (Canli, 2008). As serotonin has an important function modulating mood states and has been implicated in depression and anxiety disorders (Hariri & Holmes, 2006; Heils et al., 1996), this finding looked like a valuable step towards accounting for the relationship between neuroticism and mental health problems. Though several meta-analyses have now confirmed that the short variant allele of the 5-HTTLPR gene is associated with neuroticism (Schinka, Busch, & Robichaux-Keene, 2004; Sen, Burmeister, & Ghosh, 2004), the effect is subtle, accounting for only 3 – 4% of the total observed variance in neuroticism scores (Canli, 2008). In addition to the small effect, recent evidence shows that 5-HTTLPR variants have influence upon mood independent from neuroticism; the effect of stress upon mood is significantly larger for short allele carries than long allele carries, regardless of trait neuroticism (Verschoor & Markus, 2011).

Identifying the neural or genetic basis of a complex trait is difficult because many factors are likely to combine to produce the features that we associate with that trait (Canli, 2008). A more effective strategy may be to identify the neural or genetic basis of specific facets of neuroticism. Endophenotypes represent simpler clues to the genetic underpinnings than the disease syndrome itself. Deconstruction can result in a more straightforward genetic analysis (Gottesman & Gould, 2003). Understanding the information processing biases associated with neuroticism helps breakdown the construct of neuroticism into specific facets and may thus facilitate the identification of endophenotypes (Canli, 2008).

1.2.3 NEUROTICISM AND INFORMATION PROCESSING

Much of the research exploring the association between neuroticism and biases in information processing, focuses upon sensitivity to negative emotional and stressful information (Gotlib & Joormann, 2010; Mathews & Macleod, 1994). Despite this, theories for why some people are more inclined to process negative information are limited. Research into information processing biases, that may underlie tendency to process negative information, is limited. The research findings in this area are briefly summarised here to provide an overview of the approaches used to date to explore cognitive facets of neuroticism.

Eysenck's theory of personality characterised neuroticism as a dimension of emotional responsiveness (Eysenck & Eysenck, 1967) reflecting difficulty regulating emotions (Eysenck, 1952). Neuroticism is associated with increased reactivity to stressors (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Gunthert et al., 1999; Mroczek & Almeida, 2004; Suls & Martin, 2005) and mood instability (Jacobs et al., 2011; Miller & Pilkonis, 2006; Miller, Vachon, & Lynam, 2009; Oliver & Simons, 2004), defined as extreme and frequent fluctuations in mood over time (Trull et al., 2008). The personality trait has also been associated with increased sensitivity to error feedback (Robinson, Moeller, & Fetterman, 2010; Robinson, Ode, Moeller, & Goetz, 2007) and a desire to avoid unwanted outcomes (Elliot & Thrash, 2002). Cumulatively these findings suggest that neuroticism is associated with a tendency to find negative emotional and distressing information particularly salient.

1.2.4 BIASES IN EMOTIONAL INFORMATION PROCESSING

Neuroticism has been associated with a bias towards negative information. For instance high neuroticism is associated with recall of more negative emotional information (Lishman, 1972; Rusting & Larsen, 1998), negative personality descriptors (Martin, Ward, & Clark, 1983) self-depreciatory information (Young & Martin, 1981) and negative personal memories (Mayo, 1983; Ruiz-Caballero & Bermudez, 1995), as well as faster recall of unpleasant than pleasant memories (Lloyd & Lishman, 1975).

The trait congruency hypothesis (Rusting, 1998, 1999; Rusting & Larsen, 1998) attempts to explain these observations. Rusting (1998, 1999) built the trait congruence hypothesis from Bower's (1981, 1991) network theory of affect, which conceptualises emotions as organising nodes linking related information in memory. According to this model, when an emotion is experienced, the corresponding emotion node is activated and past events and beliefs associated with that emotion are brought to mind. Bower (1981, 1991) argued that because current emotional state activates mood congruent concepts in memory, people should find it easier to learn and remember congruent emotional material. The trait-congruency hypothesis is based on the assumption that, like negative emotion, neuroticism is associated with increased activation of negative information in memory, facilitating processing of new negative information. This form of effect has been widely documented in learning and memory literature in terms of state dependent learning (e.g., Goodwin, Powell, Bremer, Hoine, & Stern, 1969). State dependent learning however, is not normally considered to be an effect specific to emotional state; rather state dependent learning is one facet of context dependent learning (e.g., Godden & Baddeley, 1975).

The trait congruency hypothesis also shares many ideas with the concept of priming. Priming is defined as "a non-conscious form of memory that involves a change in a person's ability to identify, produce or classify an item as a result of a previous encounter with that item" (Schacter, Dobbins, & Schnyer, 2004). Though priming was originally explored in terms of perceptual processing, conceptual factors, where semantic processing is required, also elicit priming effects (Brown & Mitchell, 1994; Srinivas & Roediger, 1990). For instance, priming influences completion of word stems or fragments, decisions about the properties or category of words or objects and ability to produce items from a category in response to a category cue (Schacter et al., 2004). If neuroticism promotes processing of negative stimuli because of activation of negative emotional information in memory, we should expect to see trait congruency effects in word completion, identification and categorisation tasks.

As discussed above, trait congruency effects are widely documented in terms of autobiographical and non-autobiographical memory. In terms of influencing the interpretation or identification of information, observation of the trait congruency has been less consistent. There have been mixed results in studies of categorisation; though some studies have found neuroticism to be associated with faster categorisation of negative information (Rusting & Larsen, 1997) others have failed to replicate this effect (Matthews & Gilliland, 1999; Rusting, 1999; Rusting & Larsen, 1998). Neuroticism has been associated with faster response to negative words in lexical decision tasks, but is also associated with fast responses to neutral words. In addition, in general, all participants, regardless of neuroticism levels, are faster responding to negative than positive words (Matthews et al., 1995). The effect of faster response time to negative words in lexical decision tasks may also be limited to situations where additional semantic priming is used (Borkenau, Paelecke, & Yu, 2010). As such, there is not conclusive evidence that neuroticism primes categorisation or identification of negative information. As such, it may not be appropriate to classify the trait congruency effect as a priming effect.

The trait congruency effect has also been identified in aspects of information processing less commonly associated with priming effects. For instance, neuroticism is associated with increased attention towards and problems disengaging from negative information, however, results are mixed. Some studies have found neuroticism to be correlated with a negative biases in the dot probe task (Fox, Cahill, & Zougkou, 2010), while others have not (Chan et al., 2007; Rijsdijk et al., 2009). Neuroticism has been associated with altered attention towards stressful distractors in dichotic listening tasks, but the direction of the effect interacts with gender (Osorio, Cohen, Escobar, Salkowski-Bartlett, & Compton, 2003). Finally, high levels of neuroticism have been associated with greater interference from unpleasant words in an emotional Stroop task, but only when there is substantial cognitive load (Paelecke, Paelecke-Habermann, & Borkenau, 2012).

Cumulatively these studies suggest that neuroticism is associated with some increases in sensitivity to negative information. The trait congruency hypothesis contends that, like priming effects, this occurs because negative emotional information is already activated. The pattern of results, demonstrating a trait congruency effect, is not consistent with a standard priming effect. Alternative explanations may be considered. For instance, the association between neuroticism and heightened sensitivity to and memory for negative information may be the product of differences in processing salient information. Neuroticism may be associated with increased sensitivity to the salience of information.

In general, everyone finds negative information more salient than positive information (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Studies have demonstrated this negative bias across the population, observing an influence upon mood, attention, learning and memory. Pratto and John (1991) found that completing a Stroop task, in which personality traits were written in different coloured ink, participants were slower to name the colour of negative personality traits (e.g., sadistic) than positive traits (e.g., honest). Participants subsequently showed better recall for the negative personality traits (Pratto & John, 1991). In the field of associative learning there is evidence that negative outcome, i.e., punishment, support faster learning than positive outcomes, i.e., reward (Meyer & Offenbach, 1962; Penney, 1967; Penney & Lupton, 1961; Spence, 1966; Spence & Segner, 1967). Similarly, drive to avoid negative outcomes appears to be stronger than the drive to approach positive outcomes (Miller, 1944). This relationship was echoed in Kahneman and Tversky's (1984) concept of value function which observes that a given increase in possible loss has a greater impact on decision making than an objectively equal possible gain. These biases in processing negative information influence mood (Brickman, Coates, & Janoff-Bulman, 1978; David, Green, Martin, & Suls, 1997). For instance, Brickman (Brickman et al., 1978) observed that the euphoria reported by individuals winning the lottery, was shorter lived than the negative affect experienced following an accident.

If, as research suggests, we all find negative information more salient than positive information, it is plausible that the association between neuroticism and sensitivity to negative information has its basis in a difference in processing of salient information. If this is an accurate assumption, it would be important to explore the association between neuroticism and basic processes of encoding, remembering and learning about information. As emotional information is usually more salient than non-emotional information, to test this assumption, we have to consider biases in non-emotional information processing.

1.2.5 BIASES IN NON-EMOTIONAL INFORMATION PROCESSING

Neuroticism has been associated with biases in processes of attention independent from the emotional value of the information being processed. Like the associations between neuroticism and attention towards negative information discussed above, these biases relate to orienting and shifting of attention. Neuroticism has been associated with facilitated automatic orienting of attention (Wallace & Newman, 1998). Though visual search performance was only impaired by distracter stimuli in female participants, female participants with high levels of neuroticism were more substantially impaired by distractors (Wallace & Newman, 1998). This facilitated automatic orienting of attention may be associated with compromised control of attention (Wallace & Newman, 1998). Performance errors relating to impaired control of attention in individuals with higher levels of neuroticism occur when tasks are mundane (Fetterman & Robinson, 2011) and require little effort (Smillie, Yeo, Furnham, & Jackson, 2006).

If neuroticism were associated with impaired ability to maintain attentional focus on task relevant information, neuroticism should be associated with a range of performance errors and inconsistent performance. Neuroticism is correlated with instability of behaviour over time (Eid & Diener, 1999; Eysenck, 1985; Moskowitz & Zuroff, 2004; Murray, Allen, & Trinder, 2002), and high standard deviation in response time (Baumeister, 1998; Robinson & Tamir, 2005), indicating less regulation of behaviour (Rabbitt, Osman, Moore, & Stollery, 2001). Further, neuroticism is associated with variability or drift in self-paced automatic timing (Forsman, Madison, & Ullen, 2009; Madison, 2004, 2006). All of these factors do indeed suggest inconsistency in performance in line with impaired ability to maintain attentional focus.

Disruptions in other aspects of attention are also associated with neuroticism. For instance neuroticism is associated with problems disengaging (Bredemeier, Berenbaum, Most, & Simons, 2011) and shifting attention (Avila, 1995; Derryberry & Reed, 1994; Raymond, Shapiro, & Arnell, 1992). This may be characterised in particular by high levels of rumination associated with neuroticism (Cox, Enns, Walker, Kjernisted, & Pidlubny, 2001; Kuyken, Watkins, Holden, & Cook, 2006; Lam, Smith, Checkley, Rijsdijk, & Sham, 2003; Roberts, Gilboa, & Gotlib, 1998; Roelofs, Huibers, Peeters, & Arntz, 2008). Rumination has been defined as a “mode of responding to distress that involves repetitively and passively focusing on symptoms of distress and on the possible causes and consequence of these symptoms” (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008).

Impaired attentional control may suggest that neuroticism is associated with increased processing of specific, relevant or salient details, at the cost of peripheral information. Such a bias may also contribute to emotional instability. When negative events occur, the impact upon us depends, to some extent, on how we process the event; seeing the event as part of a wider picture can help minimise the negative impact. Problems processing events in context might arise from differences in breadth of attention or problems encoding combinations of information. While there is evidence that stress or high emotional arousal is associated with changes in attention and memory encoding, contributing to reduced processing and recall of peripheral information (Brown, 2003; Cavenett & Nixon, 2006; Christianson et al., 1991; Loftus et al., 1987), very few studies have considered whether neuroticism might be associated with such biases. Stress and high emotional arousal are also associated with changes in binding information (Mather & Sutherland, 2011). Associations between neuroticism and attending to or binding peripheral information have been approached from the study of field dependence and feature integration.

Field dependence is a term developed to describe the extent to which an individual relies upon external referents (Witkin, 1950). The concept of field dependence was initially used to describe performance in perceptual tasks such as the rod and frame task (Asch & Witkin, 1948a, 1948b; Witkin & Asch, 1948a, 1948b) and the Embedded Figures Test (Witkin, 1950; Witkin, Oltman, Raskin, & Karp, 1971). The Embedded Figures Test (EFT) requires participants to find a simple figure within a complex diagram. Poor performance on this task suggests inability to process a feature independent from its context. Participants showing poor performance may be termed field dependent. Associations between field dependency and interpersonal behaviour (Witkin & Goodenough, 1977) and social orientation (Eagle, Fitzgibbons, & Goldberger, 1966; Fitzgibbons, Goldberger, & Eagle, 1965; Rhodes, Carr, & Jurji, 1968), have been widely studied. Field dependency is associated, for instance, with intolerance of isolation (Silverman, Cohen, & Shamavonian, 1963), better memory for human faces (Messick & Damarin, 1964), and orientation toward social approval (Konstadt & Forman, 1965). While some studies have found a relationship between field dependence and neuroticism, suggesting that processing by neurotic individuals may be more dependent on and sensitive to the context in which such processing takes place (Goggin, Flemenbaum, & Anderson, 1979) other studies have found no association (Lotwick, Simon, & Ward, 1984; Taft & Coventry, 1958). The inconsistency in findings may be because neuroticism reflects a conflict between field dependence and social withdrawal (Fine, 1972). If any conclusion can be drawn from these studies, they suggest that rather than being less sensitive to contextual information, an individual with high levels of neuroticism may be more sensitive to such information.

Avisar (2011) used the Triesman feature search task (Treisman & Gelade, 1980) to test the association between neuroticism and ability to combine information. The task involves a conjunction visual search; requiring participants to find the conjunction of two features assesses ability to bind and identify conjunctions of features. Neuroticism was associated with poor search performance, suggesting impaired ability to identify the conjunction of features (Avisar, 2011).

1.2.6 SUMMARY

Neuroticism is associated with emotional instability, elevated levels of distress and altered processing of emotional information. Much research has focused on identifying biases in the processing of emotional information associated with neuroticism. It is, however, possible that differences in the processing of emotional information may arise from basic differences in information processing, such as altered processes of attention and changes in sensitivity to salient information or differences in the ability to encode conjunctions of information. Such differences may provide a mechanism for individual differences in sensitivity to negative information.

Through this thesis, I explore the relationship between neuroticism and processing of non-emotional information, with a particular focus on learning about combinations of information. Stress is associated with a shift in attention to focus on specific details (J. M. Brown, 2003; Christianson, 1992; Loftus et al., 1987) and changes in the ability to bind information (Mather & Sutherland, 2011). Associative learning theories suggest that these changes should influence ability to engage in learning about configurations, i.e., non-linear learning. As neuroticism is associated with elevated levels of distress, neuroticism may be expected to be associated with changes in ability to combine stimuli and learn about distinct combinations of stimuli.

1.3 FORTHCOMING CHAPTERS

CHAPTER 2

In this chapter I present experiments testing the association between neuroticism and non-linear discrimination learning. Non-linear discrimination learning was compared to learning a linear discrimination task to allow specific assessment of ability to learn that combinations of stimuli were associated with different outcomes from those associated with their constituent stimuli. Individuals with high neuroticism scores were found to show stronger non-linear discrimination learning than individuals with low neuroticism scores.

CHAPTER 3

To test whether the relationship between neuroticism and non-linear discrimination learning was related to ability to process global configurations, as opposed to the specific details composing those configurations, the association between hierarchical processing, as measured by the Navon task, non-linear discrimination learning, and neuroticism, was tested. Individuals who were faster identifying specific details showed limited non-linear discrimination learning relative to individuals who were faster identifying global configurations. This relationship was also seen when individuals were given practice identifying specific details or global configurations; practice identifying global configurations strengthened non-linear discrimination learning relative to practice identifying specific details. These effects were only observed for individuals with low levels of neuroticism. Though neuroticism was not associated with performance on the Navon task, the association between performance on the Navon task and ability to learn the non-linear discrimination was only observed for individuals with low levels of neuroticism. A model to account for individual differences in human non-linear discrimination learning is presented and discussed in this chapter.

CHAPTER 4

Following the results of Experiment 3 and 4, a series of experiments were conducted to test whether neuroticism and dysphoria (mild depression, as measured by the Beck Depression Inventory) were associated with any changes in tendency to focus on specific details. This chapter presents a short review of the perceptual processing tasks used to assess whether individuals focus on specific details rather than global configurations.

High BDI scores (dysphoria) were found to be associated with enhanced performance on the Embedded Figures Task. Though this was a particularly striking effect, interpretation of strong performance on this task is not straight-forward. A set of experiments using the Navon task and a feature search task were conducted to try to understand the relationship between dysphoria and performance on the Embedded Figures Task. Three experiments with the Navon task tested whether dysphoria or high neuroticism were associated with changes in ability to identify specific details, changes in ability to identify specific details while ignoring contrasting global information and changes in ability to prioritize goal relevant information. Neither high neuroticism, nor dysphoria, was associated with changes in any of these aspects of performance.

A feature search task was used to test whether neuroticism, or dysphoria, was associated with improved ability to identify conjunctions of features. There was no evidence of an association between either neuroticism or dysphoria and ability to identify feature conjunctions.

CHAPTER 5

Processes of attention have a broad influence upon learning. As such the relationship between neuroticism and specific processes of attention was explored to test whether changes in processes of attention could account for the association between neuroticism and strong non-linear discrimination learning. Sensitivity to relative validity was tested, but no association with neuroticism was observed.

Increased sensitivity to stimulus pre-exposure, with attention shifting away from irrelevant information, may have accounted for strong non-linear discrimination learning. A perceptual learning procedure was used to test whether neuroticism was associated with increased sensitivity to stimulus pre-exposure. Neuroticism was not observed to be associated with increased sensitivity; however there was some indication that individuals with low neuroticism scores were more influenced by certain aspects of stimulus pre-exposure than individuals with high neuroticism scores.

CHAPTER 6

In the concluding chapter I summarise findings and discuss how the results of these experiments relate to each other. I review various limitations of the experiments presented and make recommendations for the direction of future research.

CHAPTER 2

2 TESTING THE RELATIONSHIP BETWEEN RISK FACTORS AND TRANSFER OF LEARNING

Neuroticism is associated with high levels of stress (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Gunthert et al., 1999; Mroczek & Almeida, 2004; Uliaszek et al., 2010). Research has explored the effect that high levels of emotional arousal or stress have upon information processing, revealing a shift in attention towards central and relevant details at the cost of memory for periphery information (Brown, 2003; Christianson et al., 1991). High arousal is also associated with changes in ability to bind information, enhancing within object binding, potentially at the cost of memory for associations between items (Kensinger, 2009; Mather, 2007; Mather & Sutherland, 2011). Despite the relationship between neuroticism and stress, there has been limited research addressing the association between neuroticism and ability to form associations between stimuli. In this chapter I present experiments testing whether neuroticism is associated with changes in ability to bind multiple stimuli to mediate task performance.

Linear associative learning, where participants are required to form associations between a stimulus and an outcome, can be accounted for by biologically plausible associative models (Rescorla & Wagner, 1972). There are many occasions, however, when the relationship between stimuli and an outcome is not linear and successful performance requires learning that specific combinations of stimuli predict an outcome. To take an example, if adding substance **A** to a petri dish causes cell growth and adding substance **B** causes cell growth, it will not necessarily be the case that adding substance **A** and **B** simultaneously will produce more cell growth. In fact, it is reasonable to expect a range of outcomes to occur. For instance, the co-occurrence of substances may produce double the outcome or the substances may cancel each other out, producing no outcome.

To learn that the co-occurrence of substances produces double the outcome, participants only have to process linear relationships, that is, each stimulus is associated with the same outcome and thus the pair of stimuli can activate this outcome with twice the vigour. Acquisition of such associations can be accounted for in terms of elemental models of learning. To learn that the co-occurrence of substances produces no outcome, participants have to learn about specific combinations of stimuli, learning that the configuration has a distinct meaning, independent from its constituent stimuli.

As with linear learning, there is good evidence for neural specialisation for configural processing. For instance, the perirhinal cortex has been implicated in binding object features to develop configural object representations (Bussey, Saksida, & Murray, 2002; Saksida & Bussey, 1999). Similarly, recent models of hippocampal function suggest a role in time dependent integration of sensory information, binding episodic and semantic information to mediate behaviour (Bast, 2007; Eichenbaum, 2000).

These regions play a role in configural learning (Fanselow, 1999) and may be damaged by chronic stress (Fuchs & Flugge, 2003). If the levels of stress associated with neuroticism produce hippocampal damage sufficient to influence the function of binding multiple stimuli, neuroticism may be expected to be associated with impaired configural learning. However, previous studies demonstrating enhanced binding of task relevant information under situations of high arousal (Mather & Sutherland, 2011), suggest neuroticism may be associated with strong configural learning. The two experiments presented here use non-linear discrimination learning tasks to test the relationship between neuroticism and configural learning.

2.1 EXPERIMENT 1

Participants' ability to learn a non-linear discrimination was compared to their ability to learn a simple, linear, discrimination using a modified negative patterning problem (Redhead, 2007; Redhead & Pearce, 1995a). The negative patterning problem is one class of non-linear discrimination that has been widely used to understand how animals, including humans, learn about combinations of stimuli (Harris & Livesey, 2008; Lachnit & Lober, 2001; Shanks & Darby, 1998) and the neural mechanisms that support this learning (Driscoll, Howard, Prusky, Rudy, & Sutherland, 2005; McDonald et al., 1997). As with all non-linear discriminations, negative patterning requires participants to learn that stimuli have different meanings dependent upon their organization. In the negative patterning discrimination, two stimuli presented in isolation predict an outcome (i.e., stimulus **A** presented alone will predict the occurrence of an outcome and stimulus **B** presented alone will also predict the occurrence of an outcome) while the combination of these stimuli predict no outcome (i.e., when stimulus **A** and stimulus **B** are presented together, no outcome occurs). This discrimination can be summarised in the notation form of **A**+, **B**+, **AB**-.

Table 2 details the version of the negative patterning task used in this experiment. Participants were asked to learn about the association between three stimuli (**A**, **B** and **C**) and an outcome. Stimulus **A** alone was associated with an outcome (i.e., **A**+), the combination of stimulus **B** and stimulus **C** was associated with an outcome (i.e., **BC**+), but the combination of all three stimuli was not (i.e., **ABC**-). Therefore each stimulus was paired with the outcome on 50% of presentations.

Table 2: Experimental design for Experiment 1.

Linear	**D**-, **EF**-, **GHI**+
Non Linear	**A**+, **BC**+, **ABC**-

Participants' ability to learn the non-linear discrimination was compared to ability to learn a linear, discrimination. In the linear discrimination each stimulus was consistently presented with its associated outcome (or absence of outcome). As with all linear discriminations, it was possible to learn this discrimination by learning about the relationship between separate stimuli and their associated outcome. Learning the linear discrimination was not dependent upon learning about combinations of stimuli.

Non-linear discrimination learning should be influenced by differences in the ability to learn about combinations of relevant stimuli. Ability to learn a linear discrimination should not be influenced. Thus comparison of ability to learn a non-linear as compared to a linear discrimination should identify specific impairments in the ability to learn about combinations of relevant stimuli. To ensure that ability to learn about combinations of stimuli was not dependent on the type of stimulus used participants completed the discrimination task either with shapes or with words.

2.1.1 METHOD

2.1.1.1 PARTICIPANTS

Eighty nine university students participated for course credit or were paid £5. Seventeen participants were male, 72 participants were female. Average neuroticism score was 18.95 (7.69). Average age was 20.42 (2.40) years. Age was not significantly correlated with neuroticism score (r = 0.05, p = 0.677). Average digit span was 7.43 (0.64) digits. Digit span was not significantly correlated with neuroticism score (r = 0.09, p = 0.422). Gender was not associated with a significant difference in neuroticism score (U (17, 72) = 537.50, p = 0.485) Participants were categorised into two groups, low and high neuroticism, on the basis of a median split of neuroticism score, from the Neuroticism Extraversion Openness Personality Inventory Revised (NEO-PI-R; Costa & Mccrae, 1995). Demographics for all participants are shown in Table 3.

Table 3: Demographics for participants completing Experiment 1.

	Shapes		Words	
Neuroticism group	Low	High	Low	High
N	23	19	22	25
Neuroticism score	12.95 (3.39)	26.13 (6.57)	12.64 (3.37)	24.56 (4.41)
BDI Score	4.57 (4.00)	13.32 (8.83)	2.55 (2.46)	10.52 (7.87)
Age, years	20.52 (2.13)	19.79 (2.27)	20.45 (2.46)	20.76 (2.71)
Digit span, digits recalled	7.43 (0.81)	7.53 (0.62)	7.45 (0.90)	7.25 (0.89)
Gender (male)	5	4	6	2

2.1.1.2 APPARATUS AND MATERIALS

QUESTIONNAIRES

Participants completed a measure of working memory (digit span; Lezak, 1995) and depression (BDI; Beck, Ward, Mendelson, & Erbaugh, 1961). BDI was measured but was not relevant to the experimental outcomes described here, as such it is not discussed further. Neuroticism was measured using the neuroticism subsection of the Neuroticism Extraversion Openness Personality Inventory Revised (NEO-PI-R; Costa &

Mccrae, 1995). This subsection of the questionnaire consists of 48 items, to which participants responded true (1) or false (0). Responses were reversed for a selection of items. The total possible score was 48. I have assessed the reliability of using this presentation of the questionnaire without the other sections of the NEO-PI-R. With a sample size of $N = 206$, this implementation of the NEO-PI-R has a high internal consistency, (Cronbach's $\alpha = 0.87$) which is comparable to levels observed when the full questionnaire is administered (e.g., $\alpha = 0.89$; McCrae, Kurtz, Yamagata, & Terracciano, 2011). A separate sample ($N = 37$) was used to measure test-retest reliability. Test scores measured two weeks apart were highly correlated ($r = 0.84$, $p < 0.001$). Finally in a third sample ($N = 52$) the correlation between the scores on the NEO-PI-R as administered here with a binary item format and scores on the NEO-PI-R as administered with a five point likert scale was tested. The correlation between the two sets of scores was again high, ($r = 0.88$, $p < 0.001$).

LEARNING TASK

The learning task was embedded in a cover story describing bacteria in Petri dishes and cell growth. In the **shape condition**, Petri dishes comprised a black grid of 52 x 52mm (36 squares; 6 x 6). Each stimulus was represented by 9 brightly coloured shapes presented in random squares within the grid. Stimuli were represented by the following shapes; upright triangle, upside down triangle, square, circle, kite, pentagon, diagonal and cross. Each of the 9 shapes measured 8.5 x 8.5mm. The remaining squares in the grid were filled with darkly coloured circles. In the **word condition**, each stimulus was represented by one of 9 foods (Strawberry, Pepper, Tomato, Lemon, Kiwi, Grapes, Avocado, Banana and Cherry) presented in white letters, on a black screen, with words arranged vertically above one another. Figure 1 shows screenshots of the stimuli. Assignment of shape/word to stimulus was partially counterbalanced, such that each shape/word was assigned to a different stimulus position giving nine different organisations. Outcome 1 was shown by cells growing to cover more than half the computer screen (60 – 100%) and outcome 2 was shown by cells growing to cover less than half the screen (0 – 40%).

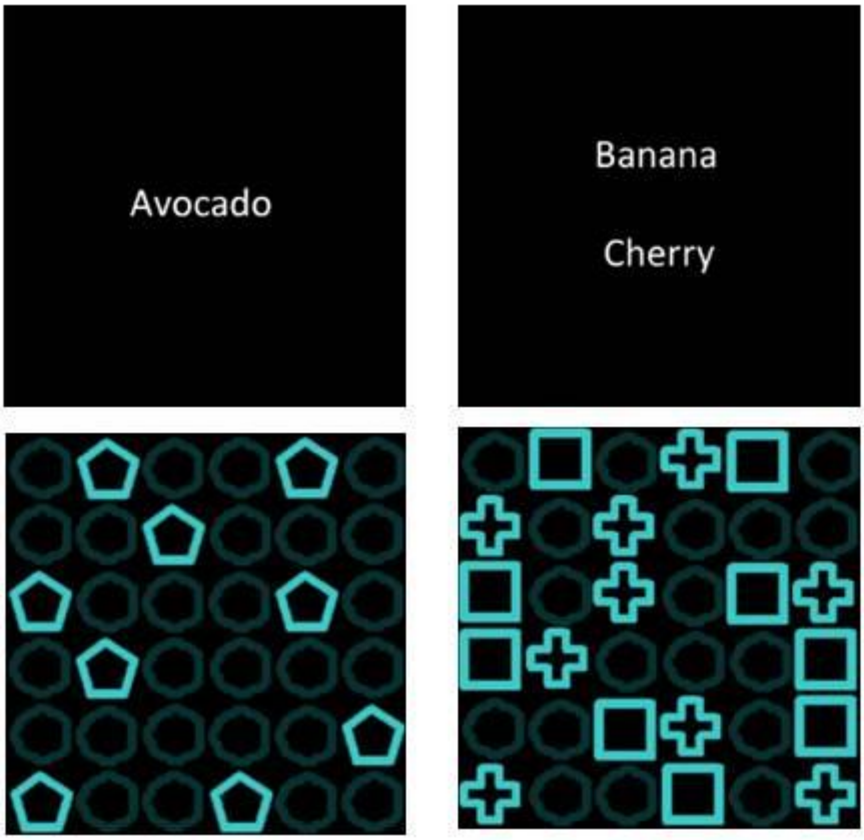

Figure 1: Screen shots from Experiment 1; Left: stimulus presentation on a single stimulus trial (i.e., **A**), Right: stimulus presentation on a double stimulus compound trial (i.e., **BC**); Top row shows word condition, bottom row shows shape condition.

2.1.1.3 PROCEDURE

Participants completed the questionnaires before the learning task. Participants were asked to imagine themselves as a biologist in a virtual laboratory. They were informed that they would be required to learn which bacteria (shapes) / food (words) caused cell growth. They were informed that they would see bacteria / foods on multiple occasions and that while on the first presentation they would have to guess how much cell growth the bacteria / food caused, the relationship would become clearer as the task proceeded.

Participants discriminated between 6 stimuli compounds; 3 events in the non-linear discrimination (**A+, BC+, ABC-**) and 3 separate events in the linear discrimination (**D-, E-, GHI+**). Participants completed 14 blocks of 6 trial types. Trial order was randomised within blocks. On each trial, a stimulus or stimulus compound was presented in the centre of the screen. Using a scale of 1 – 9 on the keyboard participants made a rating of the likelihood that the presented stimulus would cause cell growth. Participants were instructed to use the low end of the scale if they did not think the stimulus would cause an outcome and the high end of the scale if they thought the stimulus would cause an outcome.

Following a participant’s response, the outcome was presented. Eight outcome values were possible; cell growth covered less than half the screen (0%, 10%, 20%, 30%) for 4 outcomes and more than half the screen (70%, 80%, 90%, 100%) for 4 outcomes. Variation within each bracket of growth was random. This variation was introduced to maintain participants' engagement with the task. The outcome was presented for 2.5 seconds, followed by the opportunity to start the next trial.

2.1.1.4 STATISTICAL ANALYSIS

On each trial, participants provided their judgements of the likelihood of the outcome occurring. Participants' judgements across the 14 trials were averaged across 4 trial blocks. The first trial block averaged across trial 1 and 2. Each of the three successive trial blocks averaged across four trials: trial block 2 was the average of trial 3, 4, 5 and 6; trial block 3 was the average of trial 7, 8, 9 and 10; trial block 4 was the average of trial 11, 12, 13 and 14. All statistical tests were two-tailed and used a $p < 0.05$ rejection criterion with a Bonferroni correction for post hoc tests. Analysis of this experiment used a repeated measures analysis of variance (ANOVA) to establish the pattern of learning and test whether there was a significant effect of discrimination task (linear vs. non-linear). Analysis focused on participants' ability to discriminate between compounds used in the two discriminations, (i.e., to identify that some compounds were paired with outcome while others were paired with no outcome). Low and high neuroticism score was incorporated in analysis of variance as a between subjects factor.

The linear discrimination, while simpler, also provided a measure of participants' ability to learn the task. If participants were unable to learn the linear discrimination, interpretation of their performance in the non-linear discrimination would not be possible. For this reason two female participants were excluded from analysis. At the end of training these two individuals continued to rate stimuli paired with no outcome as more predictive of the outcome than stimuli paired with the outcome. One of these participants was in the high neuroticism group (NEO-N = 22), the other was in the low neuroticism group (NEO-N = 9).

2.1.2 RESULTS

In general participants' learning tracked the trained contingencies. Figure 2 shows participants' judgements of the likelihood of the outcome occurring through training. Though learning of the non-linear discrimination is weaker than learning the linear discrimination for both groups, the difference in learning between linear and non-linear discrimination appears to be less for the high neuroticism group than the low neuroticism group.

To check that stimulus type and neuroticism were not associated with any differences in overall learning, independent from our focus of interest, the difference between linear and non-linear discrimination learning, a 2x2x2x2x2 way ANOVA was conducted on participants' judgements of the likelihood of the outcome occurring. This ANOVA was conducted with the factors of; outcome predicted (outcome vs. no outcome), trial block (first vs. last), discrimination (linear vs. non-linear), stimulus (shapes vs. words) and neuroticism group (low vs. high). As training proceeded, judgements changed to reflect the contingencies to which participants had been exposed; there was a significant interaction between predicted outcome and trials (F [1, 83] = 245.96, $p < 0.001$). Participants' judgements of the likelihood of the outcome occurring increased over training for stimuli associated with the outcome and decreased over training for stimuli associated with no outcome. Neither neuroticism (F [1, 83] = 1.784, p = 0.185) nor stimulus type (F [1, 83] = 1.538, p = 0.218) showed a significant interaction with the relationship between outcome and trials; neither factor influenced overall capacity to learn.

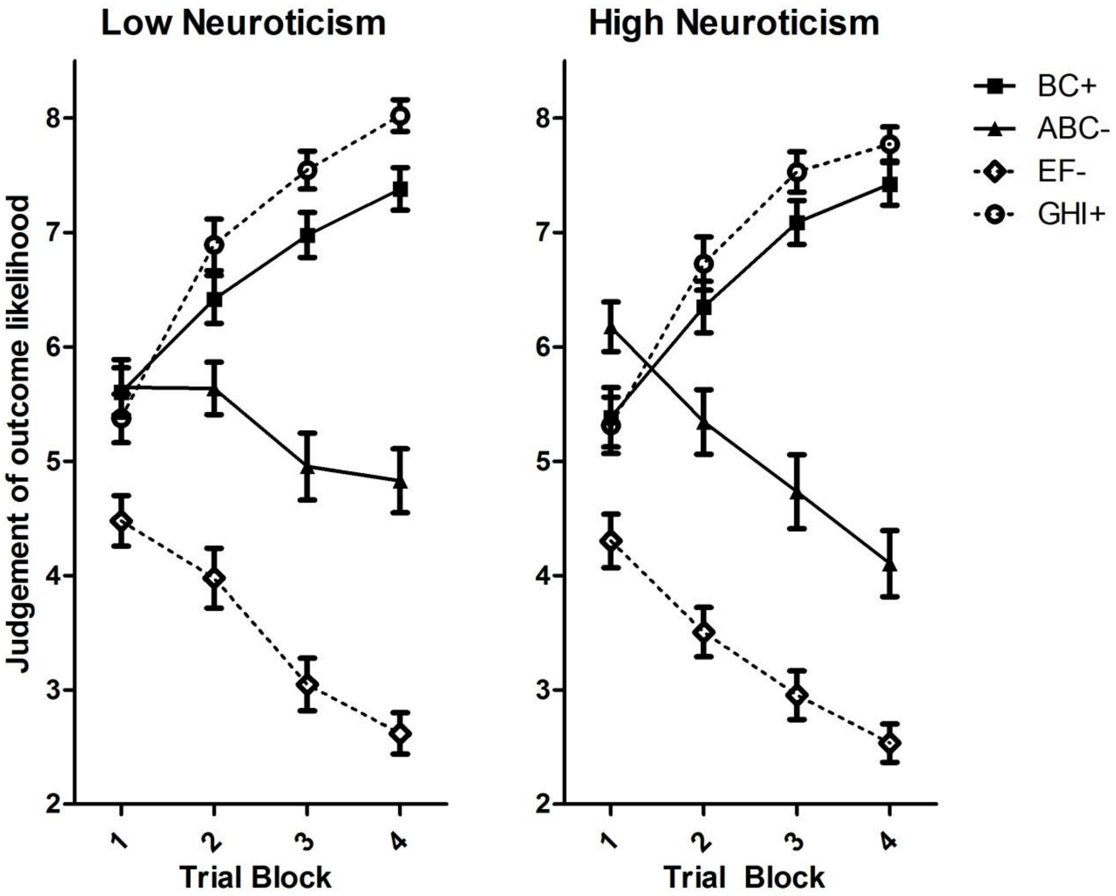

Figure 2: Judgements of the likelihood of the outcome occurring through Experiment 1.

To investigate whether discrimination learning differed between linear and non-linear tasks, discrimination scores were calculated, from judgements of the likelihood of the outcome occurring, by subtracting the rating of outcome likelihood following a stimulus compound paired with no outcome from the rating of outcome likelihood following a stimulus compound paired with outcome (i.e., non-linear discrimination score = judgements for **BC** less judgements for **ABC**; linear discrimination score = judgements for **GHI** less judgements for **EF**).

Discrimination prior to learning was tested to assess whether there were any baseline differences between low and high neuroticism groups. A 2x2x2 way ANOVA was conducted on discrimination scores from the first trial block of training, with the factors of; discrimination (linear vs. non-linear), stimulus (shapes vs. words) and neuroticism group (low vs. high).

On the first trial block of training, all participants showed stronger discrimination between compounds in the linear than the non-linear condition (F [1, 83] = 18.91, p < 0.001). However, neuroticism was not related to general pre-existing difference in processing the stimuli; there was no significant main effect of neuroticism group (F [1, 83] = 1.48, p = 0.227) and no significant interaction between discrimination task and neuroticism (F [1, 83] = 1.89, p = 0.173).

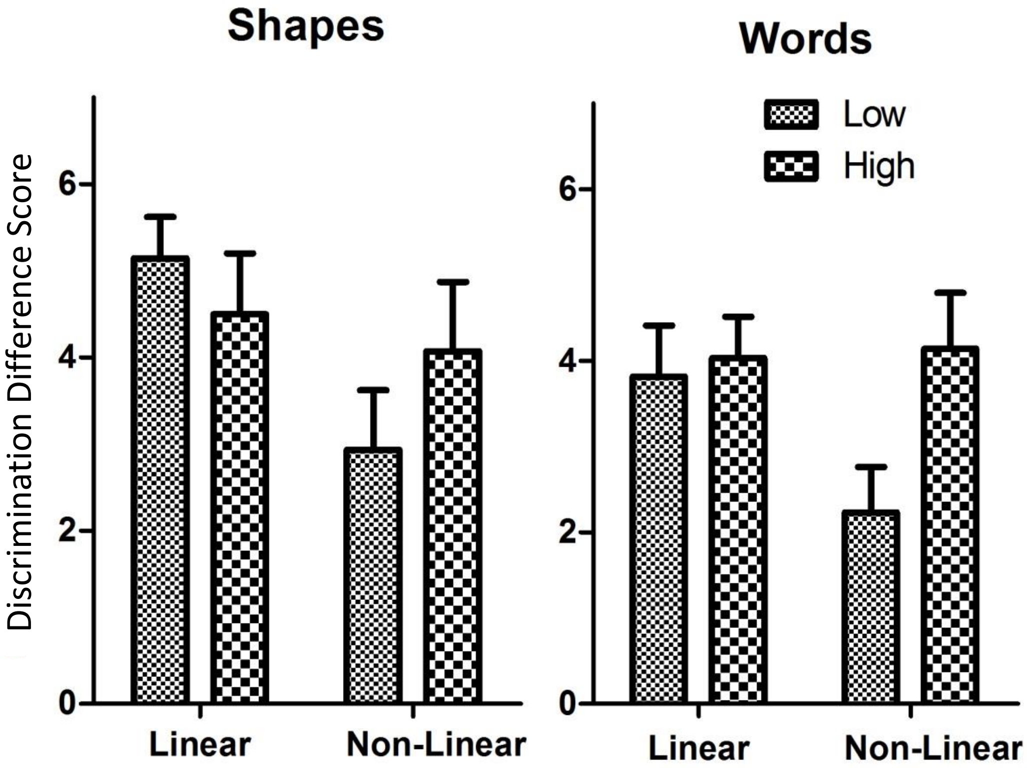

Figure 3: Discrimination Difference Scores over training in Experiment 1, for Low and High neuroticism groups.

Learning was assessed with analysis of discrimination difference scores. Discrimination difference scores were calculated by subtracting discrimination scores on the first block of training from discrimination scores on the last block. Higher values represent stronger discrimination. Figure 3, shows discrimination difference scores and indicates that the low but not the high neuroticism group found learning the non-linear discrimination more difficult than the linear discrimination.

To assess whether neuroticism scores related to variation in improvement in discrimination over training, a 2x2x2 way ANOVA was conducted with the factors of;

discrimination task (linear vs. non-linear), neuroticism group (low vs. high) and stimulus type (shape vs. word). There was a significant interaction between neuroticism group and discrimination (F [1, 83] = 5.30, p = 0.024). There was no significant main effect of stimulus type (F [1, 83] = 1.54, p = 0.218) and no significant interaction between stimulus type and task (F [1, 83] <1, p = 0.442).

Post hoc paired samples t-tests indicated that the low neuroticism group showed significantly greater learning in the linear than non-linear discrimination (t [43] = 3.95, p < 0.001). In contrast the high neuroticism group showed similar and strong learning with both discriminations; analysis revealed no significant difference between the conditions (t [42] <1, p = 0.838). The difference between the low and high neuroticism groups occurred only in terms of how the groups learnt the non-linear discrimination; discrimination difference scores were significantly higher for the high neuroticism group than the low neuroticism group in the non-linear discrimination (F [1, 83] = 5.21, p = 0.025) but not in the linear discrimination (F [1, 83] <1, p = 0.619).

To ascertain whether working memory was related to this effect, the analysis of discrimination difference scores was repeated while holding digit span as a covariate. The interaction between neuroticism group and discrimination remained significant (F [1, 82] = 5.11, p = 0.026).

2.1.3 DISCUSSION

The aim of this experiment was to test the association between neuroticism and non-linear discrimination learning. Neuroticism was associated specifically with difference in non-linear discrimination learning. Individuals with high neuroticism scores learnt both the linear and non-linear discrimination. Individuals with low neuroticism scores were impaired learning the non-linear discrimination. Neuroticism was not associated with any significant difference in linear discrimination learning. The interaction between neuroticism and non-linear learning was not dependent on stimulus type (i.e., shapes or words) or participants' working memory capacity.

2.2 EXPERIMENT 2

The previous experiment illustrated that learning about stimulus combinations was facilitated in participants with higher neuroticism scores. In Experiment 1 however, learning about stimulus combinations was the optimal strategy for discrimination. As such, while the results of Experiment 1 indicate that individuals with high levels of neuroticism are capable of learning about stimulus combinations, they do not dissociate a default strategy to bind relevant information into configuration from successful selection and implementation of the most effective strategy for discrimination. To dissociate these two possibilities Experiment 2 tested a discrimination in which stronger learning about stimulus combinations was predicted to interfere with discrimination learning. Table 4 illustrates the design of Experiment 2; in one condition (incongruent condition) learning about the combinations of stimuli should facilitate discrimination. In the other condition (congruent condition) learning about the combinations of stimuli should impede discrimination. This experimental design allows us to test the flexibility with which participants learn about combinations of stimuli.

Table 4: Experimental design for Experiment 2.

Congruent	**C**+, **CY**+, **D**-, **DY**-
Incongruent	**A**+, **AX**-, **B**-, **BX**+

In the congruent discrimination stimulus **C** predicted an outcome when presented alone and when presented in combination with stimulus **T** (i.e., **C**+ **Y**+). Similarly stimulus **D** predicted no outcome when presented alone and in combination with stimulus **Y** (**D**-, **DY**-). By learning the relationship between separate stimuli and outcomes, participants would be expected to learn that whenever stimulus **C** is presented, an outcome should occur and whenever stimulus **D** is presented no outcome should occur. In addition, participants should learn that stimulus **Y** is not predictive of whether or not an outcome will occur. While learning about the combination of stimuli will not prevent learning it is not an effective strategy for learning this task as stimulus **Y** introduces similarity between the compounds (**CY** and **DY**). Therefore, learning about the combinations of stimuli should limit discrimination as the similarity between the compounds should facilitate the partial generalisation of the compound-outcome associations between the two compounds. As these compounds are associated with different outcomes (occurrence and absence of outcome) generalisation of associative strength between the compounds is counter-productive for discrimination. In contrast, in the incongruent discrimination, learning about the combinations of stimuli is predicted to facilitate discrimination; since **A** has a different meaning in compound and alone (**A**+ **AX**-) learning that **AX** is not the same as **A** will facilitate discrimination.

If participants consistently learn about the combinations of stimuli, they should show stronger discrimination learning in the incongruent than congruent discrimination. If participants do not learn about the combinations of stimuli, they should show weaker discrimination learning in the incongruent than the congruent condition. However, if participants show flexibility in learning, only learning about the combinations of co-occurring stimuli when this is beneficial for discrimination, they should show strong discrimination learning in both conditions. As no difference between the use of words or shapes was observed in Experiment 1, and since shapes offer less opportunity for pre-task associations, only shapes were used in this experiment.

2.2.1 METHODS

2.2.1.1 PARTICIPANTS

Thirty three university students (23 female, 10 male) participated for course credit or were paid £5. Average neuroticism score was 19.45 (8.22). Average age was 22.29 (6.93) years. Age was not correlated with neuroticism score (r = 0.01, p = 0.974). Average digit span was 7.36 (0.86). Digit span was not correlated with neuroticism score (r = -0.05, p = 0.798). Neuroticism score did not differ significantly between male and female participants (U (10, 23) = 84.5, p = 0.231). As described in Experiment 1, participants were categorised into low and high neuroticism groups on the basis of a median split of neuroticism score. Table 5 shows demographics for these participants.

Table 5: Demographics for participants completing Experiment 2.

	Neuroticism group	
	Low	High
N	15	18
Neuroticism score	11.9 (3.43)	25.7 (5.10)
BDI Score	4.07 (3.99)	10.72 (8.23)
Age, years	22.5 (9.10)	22.1 (4.70)
Digit span , digits recalled	7.46 (1.20)	7.40 (0.63)
Gender (male)	6	4

2.2.1.2 APPARATUS AND MATERIALS

Questionnaires, task cover story and stimuli were used as described in Experiment 1 except for a reduction in number of stimuli. Only the following shapes were included: circle, pentagon, upright triangle, upside down triangle, hourglass and square. Assignment of shape to stimulus was partially counterbalanced, such that stimuli **A** – **D** were assigned to the circle, pentagon and the two triangles, creating four different assignments with each stimulus assigned to a different shape. These four assignments were used twice, once with **X** assigned to the hourglass shape and **Y** assigned to the square, and once with the assignment of **X** and **Y** to shape reversed.

2.2.1.3 PROCEDURE

Participants completed a learning task with two fully intermixed conditions. Full task design is shown in Table 4. In the congruent condition, stimuli **C** and **D** each predicted the same outcome regardless of the presence of an additional stimulus (**C+, CY+** and **D-, DY-**). In the incongruent condition, the presence of the additional stimulus (**X**) changed the outcome predicted by the co-occurring stimulus (**A+, AX-** and **B-, BX+**). The task consisted of 16 blocks of the 8 trial types. All other details of the procedure were as described in Experiment 1.

2.2.2 RESULTS

Analysis was conducted as described in Experiment 1. Participants' judgements across the 16 trials were averaged across 6 trial blocks. The first and the last trial block averaged across 2 trials (trial 1 and 2 for the first trial block and trial 15 and 16 for the last trial block). Each of the four other trial blocks averaged across three successive trials. Participants' judgements generally changed to reflect the trained contingencies as learning proceeded. Figure 4 shows participants' judgements of the likelihood of the outcome occurring following separate and compound stimuli. All participants learnt more with separate stimuli (i.e., **A**+, **B**-) than compound stimuli (i.e., **AX**-, **BX**+) and learnt more with stimuli in the congruent than incongruent discrimination. In terms of separate stimuli, the high neuroticism group appear to have learnt more about stimuli in the incongruent discrimination than participants in the low neuroticism group; for the high neuroticism group, there was minimal difference between the two discriminations. Though the high neuroticism group appear to have learnt less well with compound stimuli in the incongruent than congruent discrimination, this should be contrasted with the performance of individuals with low neuroticism scores who do not appear to learn anything about the compound stimuli in the incongruent discrimination.

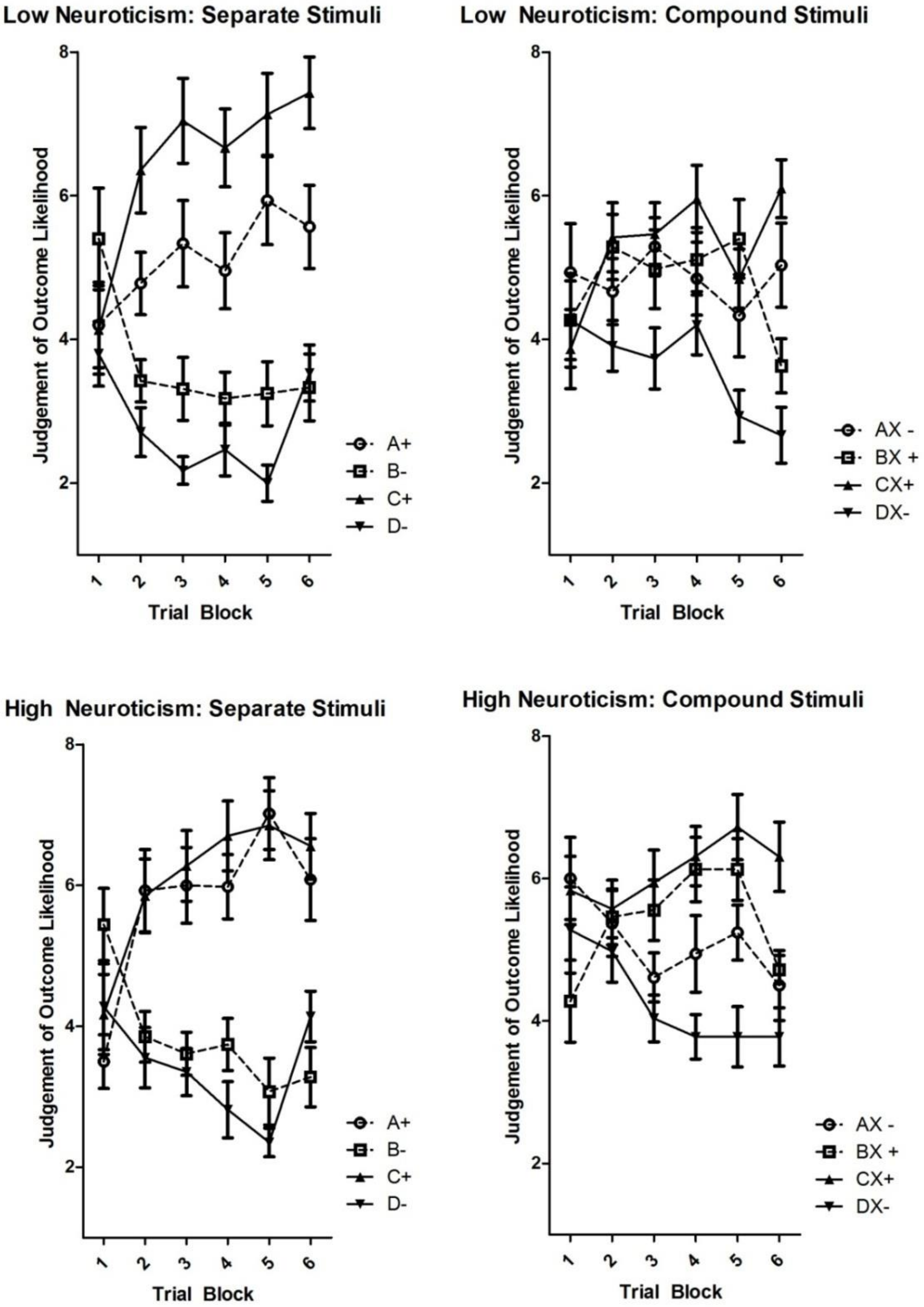

Figure 4: Judgements of the likelihood of the outcome occurring for Experiment 2; showing judgements for separate and compound stimuli in the congruent (solid lines) and incongruent (dashed lines) discriminations.

As described in Experiment 1, to check that neuroticism was not associated with any general difference in learning, independent from the distinction between congruent and incongruent discrimination, all experimental factors were entered into an ANOVA. As expected participants' judgements of the likelihood of the outcome occurring increased over training for stimuli predictive of the outcome occurring and decreased for stimuli predictive of no outcome occurring; there was a significant interaction between outcome predicted and trials (F [1, 31] = 61.37, p <0.001). As expected, there was no significant interaction between overall capacity to learn and neuroticism group (F [1, 31] < 1, p = 0.690). There was a significant three way interaction with number of stimuli, i.e., outcome predicted x trial x stimulus number (F [1, 31] = 5.81, p = 0.022). Though the increase in discrimination was stronger for separate stimuli (i.e., **A** and **B**) than compounds (i.e., **AX** and **BX**), post hoc analysis revealed a significant trial by outcome interaction for separate (F [1, 31] = 49.83, p <0.001) and compound stimuli (F [1, 31] = 11.89, p <0.01).

As in Experiment 1 discrimination scores were calculated. Within a discrimination condition, judgements of outcome likelihood, following stimuli predicting outcome were compared to judgements following stimuli predicting no outcome, such that discrimination scores in the incongruent condition reflected judgements made to (**A** and **BX**) – (**B** and **AX**) and discrimination scores in the congruent condition stimuli reflected judgements made to (**C** and **CY**) – (**D** and **DY**). On the first block of training, participants showed stronger discrimination scores in the congruent than incongruent condition (F [1, 31] = 10.23, p < 0.01). There was no main effect of neuroticism group (F [1, 31] < 1, p = 0.528) and no interaction between neuroticism group and discrimination task (F [1, 31] = 1.56, p = 0.220). This confirms that there was no initial difference between the groups in basic discrimination.

To determine the effect of training upon discrimination, discrimination difference scores were calculated as described in Experiment 1. Discrimination difference scores, presented in Figure 5, indicate that where failure to learn about the combinations of stimuli should enhance performance (i.e., the congruent discrimination) individuals with low neuroticism scores performed better than individuals with high neuroticism scores. Where failure to learn about the combinations of stimuli should impair discrimination learning (i.e., the incongruent condition), individuals with low neuroticism scores performed less well than individuals with high neuroticism scores.

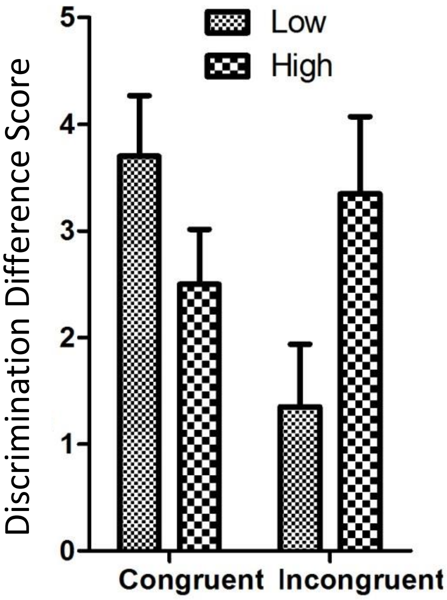

Figure 5: Discrimination difference scores for Experiment 2.

A 2x2 way ANOVA was conducted on discrimination difference scores with the factors; discrimination task (congruent vs. incongruent) and neuroticism group (low vs. high). There was a significant interaction between discrimination task and neuroticism (F [1, 31] = 10.26, $p < 0.01$). Post hoc analysis revealed that the low neuroticism group showed a stronger learning in the congruent discrimination than the incongruent discrimination (t [14] = 3.23, $p < 0.01$). In contrast the high neuroticism group showed no effect of discrimination (t [17] = 1.42, $p = 0.173$); learning was similar in both conditions. Though the graph suggests differences between the two groups in performance on each of the conditions, post hoc analysis (with Bonferroni correction applied to control for multiple comparisons, significance level is 0.025) suggests only marginal differences between the two groups in the congruent (F [1, 31] = 3.59, $p = 0.068$) or incongruent (F [1, 31] = 4.35, $p = 0.045$) discriminations.

As with Experiment 1 the influence of digit span on the interaction between learning and neuroticism was tested by holding digit span as a covariate. The interaction between neuroticism group and discrimination again remained significant (F [1, 30] = 9.87, $p < 0.01$).

2.2.3 DISCUSSION

The aim of this experiment was to test the flexibility with which individuals with high neuroticism scores learnt about stimulus combinations. Neuroticism was associated with strong non-linear discrimination learning, but individuals with high neuroticism did not appear to learn about stimulus combinations flexibly. In the congruent discrimination condition, learning about combinations of stimuli may have impaired discrimination learning. If individuals with high neuroticism scores had learnt about combinations of stimuli flexibly they should have shown strong discrimination learning in both the congruent and incongruent condition. Individuals with high neuroticism scores were able to learn the non-linear discrimination, requiring the combination of co-occurring stimuli to be encoded. This contrasted the performance of individuals with low neuroticism scores who were significantly impaired learning the incongruent discrimination, relative to the congruent discrimination.

While individuals with high neuroticism scores showed comparable discrimination learning in the two conditions, there was a non-significant trend for individuals with low neuroticism scores to show stronger learning than individuals with high neuroticism scores in the congruent condition. For a conclusive argument that high neuroticism is associated with flexible learning about combinations of stimuli, individuals with high neuroticism scores might be expected to show stronger discrimination learning than individuals with low neuroticism scores in both conditions, as opposed to simply the incongruent condition.

The results suggest that the high neuroticism group may be using the combination of stimuli in the congruent discrimination even though this might not be the most effective strategy for learning. Individuals with low neuroticism scores seemed less likely to learn about the combinations of stimuli. This resulted in poor learning in the incongruent discrimination, but may explain this group’s a substantial advantage, learning the congruent discrimination.

2.3 GENERAL DISCUSSION

These studies examined individual differences in the ability to learn non-linear discrimination tasks. The results suggest that individuals differ in their ability to learn these discriminations. It is hypothesized that these differences may reflect the acquisition of configural representations. In conditions where combinations of stimuli needed to be treated as distinct from their constituent stimuli, individuals with high neuroticism scores learnt more than individuals with lower neuroticism scores.

It cannot simply be argued that neuroticism improves or interferes with learning. The discrimination tasks used here suggest that while individuals with higher neuroticism scores were able to solve complex discrimination problems, requiring them to learn about combinations of stimuli, did not consistently perform better than the low neuroticism group across all conditions. This suggests that the performance advantage may be specific to ability to learn about combinations of stimuli as distinct from their constituent elements.

Previous studies addressing variability in non-linear learning have focused upon speed and capability as explanations for individual difference. For instance, Shanks and Darby (1998) suggested that for rule induction to occur, allowing generalisation of the acquired negative patterning rule, strong basic associations needed to be formed first. Individuals with poor discrimination learning did not go on to show rule induction (Shanks & Darby, 1998) and rule induction was less likely to occur when participants performed a concurrent task (Smith & Shapiro, 1989; Wills et al., 2011). This suggests that generalisation facilitated by rule induction may require conscious attention.

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These previous studies suggest that stronger configural processing may be expected when individuals can show concentrated attention. While this does not appear to accord with observations of disruptions in attention associated with neuroticism (Bredemeier et al., 2011; Fetterman & Robinson, 2011), there is some evidence from studies conducted in the work place, suggesting that individuals with high levels of neuroticism may be better able to maintain task directed attention in situations of high work pressure than individuals with lower levels of neuroticism (Smillie et al., 2006). At this stage, however, it is not clear whether it would be plausible to account for the strong non-linear discrimination learning, associated with neuroticism, in terms of differences in ability to maintain task directed attention. Though there was no observed association between neuroticism and working memory capacity, as measured by the digit span assessment, further research is necessary to fully understand the role that attention and working memory capacity may play in mediating the association between neuroticism and non-linear learning.

The results presented here do accord with the findings of improved binding of relevant information under conditions of high arousal (Mather & Sutherland, 2011). Neuroticism is associated with chronic stress, and as such, patterns of information processing, associated with high stress may be expected. The task design used here allowed assessment of ability to learn associations between outcomes and combinations of stimuli. High neuroticism was associated with stronger non-linear learning in particular. Linear discriminations, where associations had to be formed between a single stimulus and an outcome, were learnt by both the low and high neuroticism groups. This suggests that high neuroticism may be associated with a change in the ability to bind co-occurring stimuli and learn about these distinct combinations of stimuli, as opposed to a more general improvement in ability to associate stimuli with outcomes.

Though high levels of arousal have been associated with enhanced binding of relevant information (Mather & Sutherland, 2011), high arousal is also associated with a shift in attention away from context or peripheral information (Brown, 2003; Cavenett & Nixon, 2006; Christianson et al., 1991). High scores on the Beck Depression Inventory, reflecting dysphoria or mild depression, have similarly been associated with reduced sensitivity to context or peripheral information (Baker et al., 2010; Msetfi et al., 2005) and studies have suggested that both low mood and high arousal may be associated with an increased focus on specific details (Basso, Schefft, Ris, & Dember, 1996; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). This would suggest that in depression and anxiety, both highly correlated with neuroticism, we might expect to see reduced ability to combine specific details with context information. The two experiments presented here looked only at learning with specific details, where all information considered was relevant to the task in question. However, the results presented here do support the contention that, like depression and anxiety, neuroticism may be associated with impairments in binding task relevant information with periphery or context information. The pattern of results observed in these experiments indicated that participants with higher neuroticism scores engaged less generalisation of associative strength between separate stimuli and compounds than participants with lower neuroticism scores. As generalisation occurs to the extent that stimuli and compounds are perceived as similar, incorporating context information into the stimulus representations should increase the perception of similarity. Being less sensitive to context information is thus one factor that may have reduced the extent to which generalisation occurred for participants with high neuroticism scores, improving non-linear discrimination learning. In Chapter 5, I report two studies testing whether neuroticism is associated with changes in attention likely to prioritise relevant information relative to context information.

More generally, the results presented here suggest that neuroticism might be associated with altered information processing and learning independent from the emotional content of information. This suggests that associative learning tasks, like the ones used here, may offer an opportunity for further exploration of information processing biases associated with neuroticism.

CHAPTER 3

3 IS THERE A ROLE FOR INDIVIDUAL DIFFERENCES IN PERCEPTUAL PROCESSING IN EXPLAINING VARIATION IN GENERALISATION?

In the introduction internal and external factors influencing ability to learn about combinations of stimuli were considered. In Chapter 2, I reported two experiments exploring the relationship between neuroticism and non-linear learning. These studies identified an association between neuroticism and variation in the ability to learn about combinations of stimuli. In this chapter, I expand upon this observation of individual differences in ability to learn a non-linear discrimination and test a potential mechanism that might account for such variability; the tendency to focus on specific details as compared to global information.

States of high arousal are associated with a tendency towards attending to and remembering specific as opposed to peripheral information (Brown, 2003; Cavenett & Nixon, 2006; Christianson et al., 1991) and enhanced binding of relevant features (Mather & Sutherland, 2011). Enhanced binding relates directly to strong non-linear discrimination; being able to bind specific and relevant co-occurring stimuli together should facilitate the configural learning required to learn a non-linear discrimination.

The effect that focusing on the specific details should have upon ability to learn about combinations of stimuli is less clear.

The distinction between focusing on specific details as opposed to global information is of particular interest because of its relationship to the distinction between learning with stimulus compounds, where the separate stimuli (specific details) are discernible, relative to learning with stimulus compounds where the global representation of the configuration is likely to be processed. As discussed in Chapter 1, the extent to which in non-linear learning is observed changes as the stimulus dimensions varied are changed. Unimodal or integral stimuli for instance may facilitate non-linear learning to a greater extent than multimodal and separable stimuli (Honey & Hall, 1989; Melchers et al., 2008; Myers et al., 2001; Rescorla & Coldwell, 1995). When integral stimuli, such as hue, are combined, the specific constituent stimuli may not be readily discernible. Similarly, it has been argued that perceptual interaction reduces ability to identify separate stimuli within a configuration when unimodal stimuli are used (Myers et al., 2001). As such, we may expect a tendency to focus on specific details to reduce capacity for non-linear learning.

The experiments presented here test whether ability to learn a non-linear discrimination is associated with a tendency towards processing specific details as opposed to global information. Individuals differ in their tendency to processes global or local level information (Navon, 1977). Global processing is associated with better recognition of faces (Macrae & Lewis, 2002; Perfect, 2003), a task thought to be highly sensitive to configural processing (Diamond & Carey, 1986; Leder & Bruce, 2000; Maurer, Le Grand, & Mondloch, 2002; Tanaka & Farah, 1993) and slower recognition of halves of a composite face (Weston & Perfect, 2005; Young, Hellawell, & Hay, 1987). Hierarchical perception tasks, like the Navon task, are widely used to test whether individuals tend to process global level information better than specific (local) details, and in particular, whether low mood or high arousal are associated with a tendency towards processing specific details (Basso et al., 1996; Fredrickson & Branigan, 2005; Gasper & Clore, 2002).

The Navon (1977) hierarchical perception task presents participants with two letters (i.e., **S** and **H**) so that large letters (global) are constructed out of small letters (local). On different trial blocks, participants are asked to report the large letter or the small letter. The letters presented in these hierarchical stimuli are equally complicated and identifiable. Three effects can be established from participants' response time (Yovel, Revelle, & Mineka, 2005). Navon found that participants responded faster when identifying a global target letter than when identifying a local target letter; this has been termed the "global precedence effect" (Navon, 1977). Navon also found that responding to local target letters was particularly impaired when the global level letter was incongruent (Navon, 1977). This Stroop-like effect has been termed a "global interference effect" (Kimchi, 1992). Other researchers have identified a third effect, a local interference effect, where incongruent local level information slows participants' responding to global target letters (Yovel et al., 2005). These differences in the ability to identify global targets may reflect differences in a common configural learning system that underlies the perception of global stimuli and the ability to configure stimuli during learning.

The two experiments presented here test whether individual differences in tendency towards global or local processing, as measured in the Navon task, are associated with differences in non-linear discrimination learning. The second experiment tests whether experience finding targets presented at a global or local level influences subsequent non-linear discrimination learning. The experiments presented here will further assess whether a tendency towards processing specific details can account for the association between neuroticism and strong non-linear discrimination learning observed in Experiments 1 and 2.

3.1 EXPERIMENT 3

This experiment tested the hypothesis that individual differences in tendency towards global or local processing, as measured by the Navon task, would be associated with ability to engage in non-linear discrimination learning, using the modified negative patterning discrimination described in Experiment 1. As described in Experiment 1, learning was assess with both shapes and words to test whether stimulus type interacted with global or local processing to influence discrimination learning. Neuroticism was measured to assess whether the relationship between neuroticism and non-linear discrimination learning could be explained by individual differences in tendency towards global or local processing.

3.1.1 METHOD

3.1.1.1 PARTICIPANTS

Sixty six university students participated for course credit or were paid £5 for their participation. Average participant age was 20.36 (2.23) years. Age was not correlated with neuroticism score, as measured by the NEO-PI-R ($r = 0.07$, $p = 0.579$). Average working memory capacity, as measured by digit span, was 7.46 (0.66) digits. Digit span was not correlated with neuroticism score ($r = 0.08$, $p = 0.509$). Neuroticism score did not differ significantly between male and female participants ($U = 286$, $p = 0.588$).

Forty one participants completed this task with shape stimuli, 27 participants completed this task with word stimuli. Participants completing the task in different stimuli conditions did not differ significantly in neuroticism score ($t [64] < 1$, $p = 0.939$), digit span (t [63] < 1, p = 0.821), age (t [66] < 1, p = 0.306) or gender (t [66] < 1, p = 0.530).

3.1.1.2 APPARATUS AND MATERIALS

Participants completed the digit span assessment (Lezak, 1995) and the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995) and a negative patterning task, as described in Experiment 1.

The Navon task, presented on a computer (programmed in Visual Basic), used four separate stimuli; two congruent stimuli (a large **S** made up of small **S**s and a large **H** made up of small **H**s) and two incongruent stimuli (a large **S** made up of small **H**s and a large **H** made up of small **S**s). Stimuli are shown in Figure 6. All stimuli consisted of white letters presented on a black background. Stimuli were presented in a square with the large letters spanning 5.5 x 5.5 cm (6.3° x 6.3°) and the small letters spanning approximately 0.5cm x 0.5cm (0.6° x 0.6°).

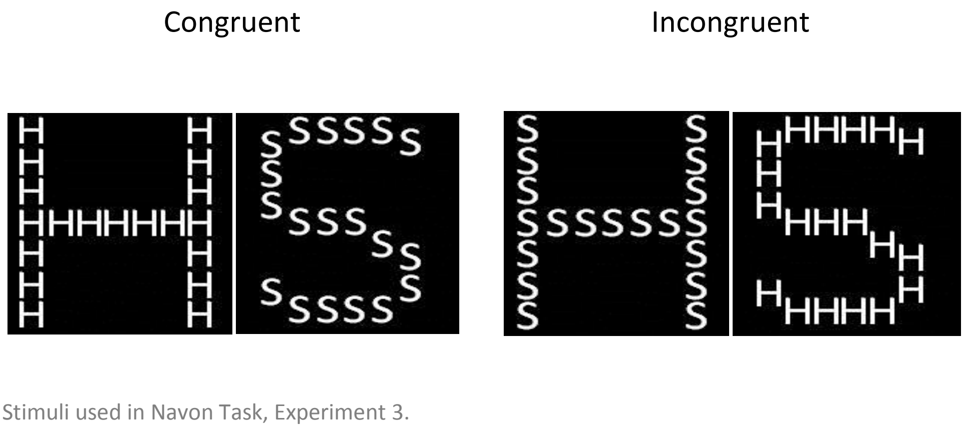


Figure 6: Stimuli used in Navon Task, Experiment 3.

3.1.1.3 PROCEDURE

Participants completed tasks in the following order; NEO-PI-R, digit span, learning task and Navon task. The negative patterning task followed the design show in Table 6, where participants were asked to learn about outcomes associated with stimuli presented as grids of shapes. This negative patterning task was completed as described in Experiment 1.

Table 6: Experimental design for Negative Patterning task, Experiment 3

Linear	**D**-, **EF**-, **GHI**+
Non Linear	**A**+, **BC**+, **ABC**-

Navon Task

Participants were informed that they would be presented with a series of large letters composed of small letters and on successive blocks they would be asked to identify the large letter or the small letters. Participants were warned that the letters would be presented for a very short period of time.

Participants completed eight blocks of 16 trials. Each trial block contained 8 **S** stimuli and 8 **H** stimuli. Half the stimuli were congruent, half incongruent. The order of stimuli presentation was randomised within each block. Through half of the trial blocks participants identified the small letters; through the other half of the trial blocks participants identified the large letters. The type of trial block alternated and half of the participants started by identifying the large letters while half started by identifying the small letters.

On each trial a fixation point was presented in the centre of the screen for 500 ms. This was succeeded by a stimulus presented for 40 ms. A mask replaced the stimulus and remained on the screen until participants made a response. Following their response there was a 300 ms pause before the next trial. Participants responded **S** or **H** using keys on the keyboard, with their left hand responding to **S** and their right hand responding to **H**. Response time was measured from stimuli onset. Response accuracy was recorded.

3.1.2 RESULTS

Trial blocks were calculated and learning analysed as described in Experiment 1. As described in Experiment 1, if participants were unable to learn the linear discrimination, interpretation of their performance in the non-linear discrimination would not be possible. Two participants were excluded from analysis. At the end of training these two individuals continued to rate stimuli paired with no outcome as more predictive of the outcome than stimuli paired with the outcome. One of these participants had completed the task with words, one with shapes. Both participants were female. Following this exclusion criterion, 38 participants completed this task using shape stimuli (22 low neuroticism; 16 high neuroticism), 26 completed the task using word stimuli (11 low neuroticism; 15 high neuroticism). Discrimination learning was analysed for all participants prior to exploring the interaction between discrimination learning and performance on the Navon task.

Before addressing whether performance on the Navon task related to non-linear discrimination learning, this analysis tests how the participant group as a whole learnt the linear and non-linear discrimination. As well as providing a comparison for subsequent analysis of the relationship between performance on the Navon task and discrimination learning, the analysis allows us to test whether stimulus type had any influence upon discrimination learning. As observed in Experiment 1, all participants showed a pattern of learning expected following the training. Figure 7 shows participants' judgements of the likelihood of the outcome occurring. Judgements increased over training for stimuli combinations predictive of the outcome (**BC** and **GHI**) and decreased over training for stimuli combinations not predictive of the outcome (**ABC** and **EF**).

To check that stimulus type did not have any substantial effect upon learning, a 2x2x2X2 way ANOVA was conducted on judgements of the likelihood of the outcome occurring with the factors of; predicted outcome (outcome vs. no outcome), discrimination (linear vs. non-linear), trial block (first vs. last) and stimulus type (shapes vs. words). Over training participants' judgements of outcome likelihood increased for stimuli predictive of cell growth and decreased for stimuli predictive of no cell growth; there was a significant interaction between predicted outcome and trials ($F [1, 62] = 174.22$, $p < 0.001$). As expected, there was no signification interaction between stimulus type, predicted outcome and trials ($F [1, 62] < 1$, $p = 0.614$). There was no significant main effect of stimulus type ($F [1, 62] < 1$, $p = 0.760$).

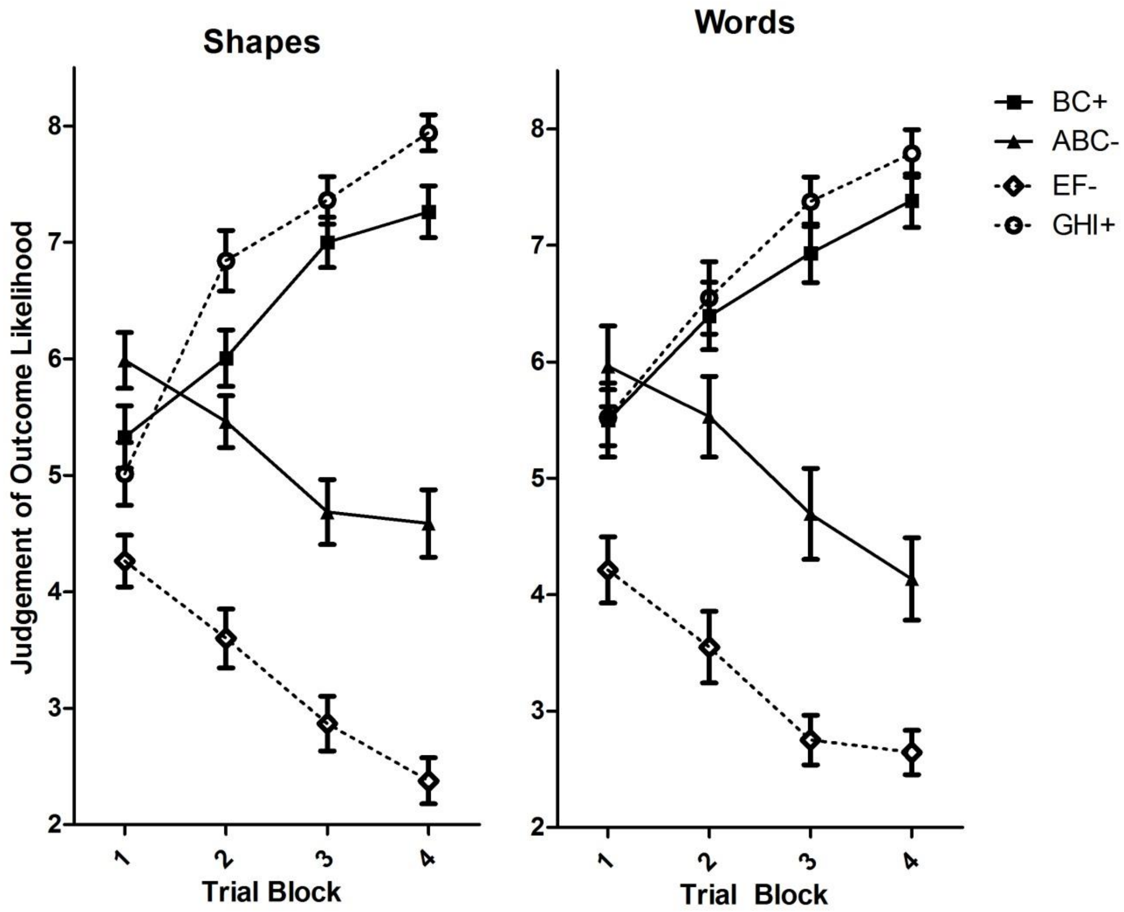


Figure 7: Judgements of the likelihood of the outcome occurring for Experiment 3, split by stimulus type.

As described in Experiment 1, judgements of the likelihood of the outcome occurring were used to calculate discrimination scores. A 2x2 way ANOVA was conducted on discrimination scores on the first trial block of training to test whether group differences were present prior to training. The ANOVA included the factors of discrimination task (linear vs. non-linear) and stimulus type (shapes vs. words). From the start of training participants showed stronger discrimination with the linear than non-linear task; there was a main effect of discrimination task, (F [1, 62] = 17.82, p <

0.001). There was no significant interaction between discrimination task and stimulus type, (F [1, 62] <1, p = 0.633) and no main effect of stimulus type (F [1, 62] = 1.26, p = 0.266).

Discrimination differences scores were calculated, as described in Experiment 1, to give a measure of learning across training. Figure 8, showing discrimination difference scores, suggests that, looking at participants as a single group, there was no overall effect of discrimination task. A 2x2 way ANOVA was conducted on discrimination difference scores, including the factors of discrimination (linear vs. non-linear) and stimulus type (shape vs. word stimuli). There was no main effect of discrimination (F [1, 62] = 2.78) and no significant interaction with stimulus type (F [1, 62] = 1.98).

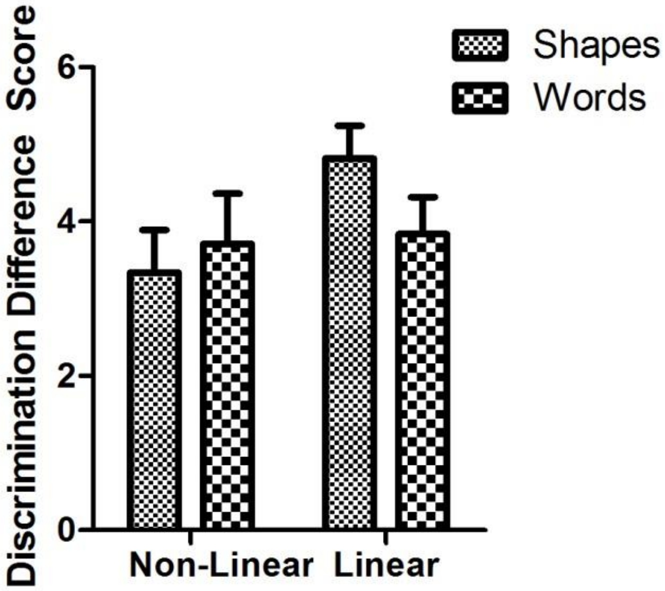


Figure 8: Discrimination Difference Scores for Experiment 3, split by stimulus type.

Overall participants learnt the non-linear discrimination as well as they learnt the linear discrimination and no interactions with stimulus type were observed. However, there was more variance in the non-linear discrimination difference scores (SEM = 0.42) than the linear discrimination difference scores (SEM = 0.32). Previous accounts of variation in non-linear learning have considered working memory capacity as an explanatory factor. Working memory capacity, here measured by digit span, was not significantly correlated with discrimination difference score for either the linear (r = 0.07, p = 0.959) or non-linear (r = -0.11, p = 0.377) condition. As such it would not seem that working memory capacity could account for variation in non-linear discrimination learning. Further it does not seem that strength of learning provides a strong prediction of ability to learn about distinct configurations of stimuli. Strength of learning, as measured by discrimination difference score in the linear condition, did not correlate significantly with discrimination difference scores for the non-linear condition (r = 0.203, p = 0.108).

INDIVIDUAL DIFFERENCES IN LEARNING: LEVEL OF PROCESSING AND NEUROTICISM

Response times and response accuracy on the Navon task were recorded for four different trial types; global congruent, global incongruent, local congruent and local incongruent. Response times on correct trials only were analysed (Navon, 1977). To ensure that differences in response times between the trial types were not caused by occasional incidents of participants responding before they had seen the stimulus or some general lack of attention, outlying response times were removed from the analysis (Ratcliff, 1993). Response times that were greater than one standard deviation above or below the mean for that trial type, for that participant, were removed. This resulted in, on average, 1.5 responses being excluded for each participant.

To determine tendency towards local processing, response times on incongruent trials were analysed. A longer response time on local incongruent trials relative to global incongruent trials indicated that the information presented at the global level had an influence on responding to information presented at the local level, i.e., a global interference effect, here termed global processing. Longer response times on global incongruent trials relative to local incongruent trials suggested that the information presented at the local level had an influence on responding to information presented at the global level, i.e., a local interference effect, here termed local processing. To reach a single score giving a reflection of local and global interference effect, global/local scores were calculated from response times. This was the difference in response time between responding to a local incongruent trial and a global incongruent trial; response times on global incongruent trials were subtracted from response times on local incongruent trials. The mean global/local score was 3.01 (5.73).

Participants scoring below the average global/local score were categorised as adopting a tendency towards local processing (N = 30). Participants scoring above the average were categorised as adopting a tendency towards global processing (N = 34). Average response accuracy, as a percentage of total trials completed, was 86.98%.

There was no significant difference in response accuracy between the local and global groups (t [62] < 1, p = 0.539). These groups did not differ in working memory capacity, as measured by the digit span assessment (t [62] < 1, p = 0.471), age (t [62] < 1, p = 0.409), or gender (t [62] < 1, p = 0.653). Further, these two groups did not differ in neuroticism score (t [62] < 1, p = 0.260). In the local group, 17 participants completed the task with shapes, 13 with words. In the global group, 21 participants completed the task with shapes, 13 with words.

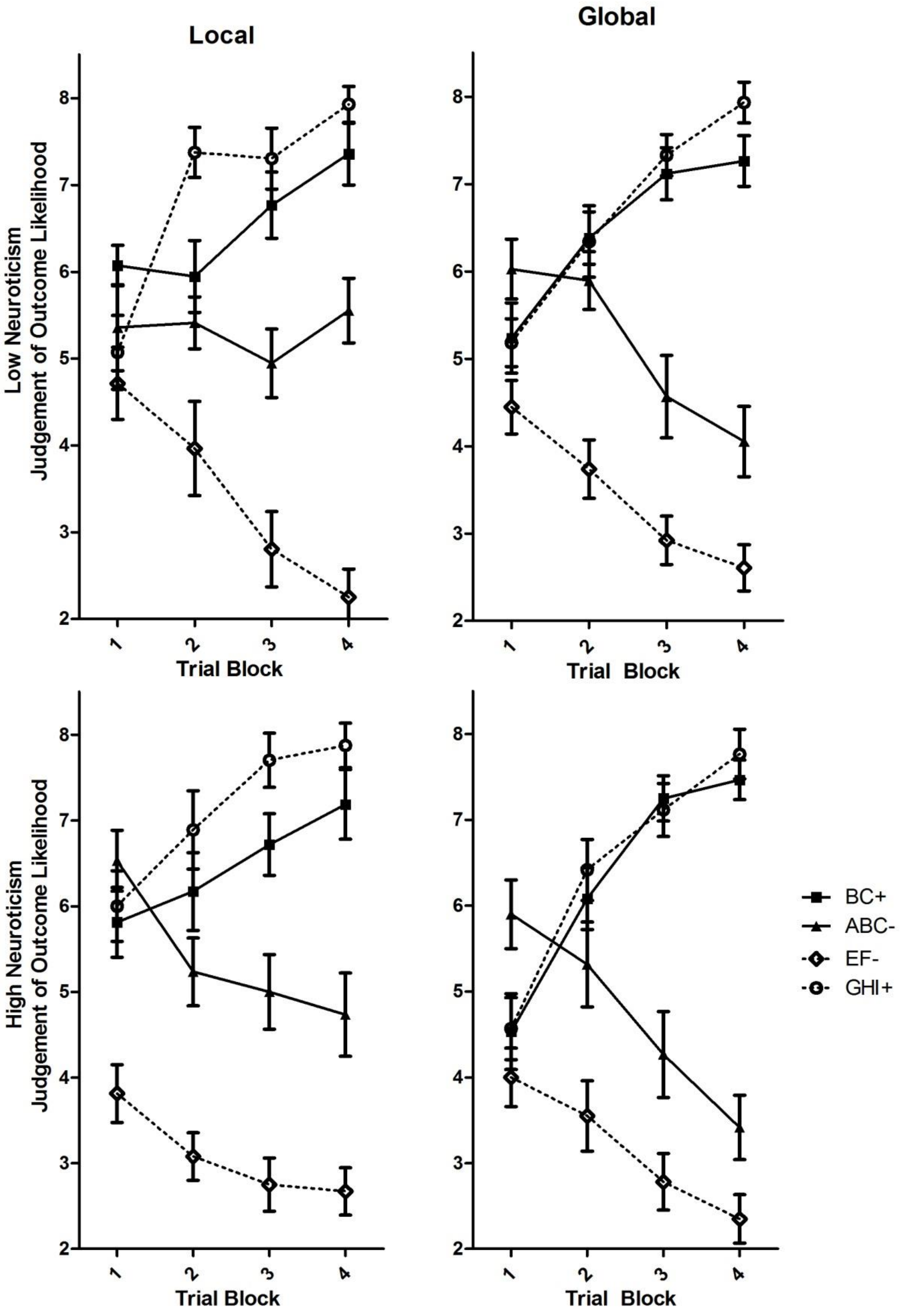


Figure 9: Judgements of the likelihood of the outcome occurring for Experiment 3, split by level of processing for low and high neuroticism groups.

Having split the participants into two groups on the basis of performance on the Navon task, we can test whether performance on the Navon task was related to discrimination learning. First we can check whether all participants showed a pattern of learning expected following the training. Figure 9 shows participants' judgements of the likelihood of the outcome occurring through training, split by level of processing; though non-linear discrimination learning appears to be stronger for the global than the local group, both groups show learning in line with the trained contingencies. A 2x2x2x2x2x2 way ANOVA was conducted on judgements of outcome likelihood with the factors of; predicted outcome (outcome vs. no outcome), discrimination (linear vs. non-linear), trial block (first vs. last), stimulus type (shapes vs. words), neuroticism group (low vs. high) and level of processing (local vs. global). Over training participants' judgements of outcome likelihood increased for stimuli predictive of the outcome and decreased for stimuli predictive of no outcome; there was a significant interaction between predicted outcome and trials (F [1, 56] = 169.64, $p < 0.001$). However, there was also a significant three way interaction between predicted outcome, trials and level of processing (F [1, 56] = 6.05, $p = 0.017$). This might suggest that the two groups, local and global, differed in overall discrimination learning. This may make it harder to analyse the effect of interest, that is, whether the two groups differed in non-linear discrimination relative to linear discrimination. Despite this interaction however there was a significant interaction between predicted outcome and trials for both local (F [1, 26] = 52.05, $p < 0.001$) and global (F [1, 30] = 129.91, $p < 0.001$) groups, indicating that overall the two groups both learnt the trained discrimination. There was no significant interaction between predicted outcome, trials, level of processing and neuroticism score (F [1, 56] < 1, p = 0.34). This suggests that there were no group differences in overall ability to engage in discrimination learning.

A 2x2x2x2 way ANOVA was conducted on discrimination scores on the first trial block of training to test whether group differences were present prior to training. The ANOVA included the factors of discrimination (linear vs. non-linear), stimulus type (shapes vs. words), neuroticism group (low vs. high) and level of processing (local vs. global). From the start of training participants found it easier to discriminate between stimuli in the linear than non-linear task; there was a main effect of discrimination task, (F [1, 56] = 14.17, p < 0.001). There was no significant interaction between discrimination task and level of processing, (F [1, 56] < 1, p = 0.326), however, there were significant interactions between discrimination task and neuroticism group (F [1, 56] = 8.87, p < 0.01), and discrimination task, neuroticism group and level of processing (F [1, 56] = 4.10, p = 0.048). Analysis of group differences in learning the linear and non-linear discrimination would be clearer if there were no group differences at baseline, prior to training. It should be noted here though that only the high neuroticism group show an effect of level of processing prior to training.

Post hoc analysis revealed that at the start of training the high neuroticism group showed an effect of discrimination task (F [1, 27] = 18.31, p < 0.001), with stronger discrimination in the linear than non-linear task, not shown by the low neuroticism group (F [1, 29] < 1, p = 0.527). This interaction between discrimination and neuroticism was more pronounced for individuals learning with words (F [1, 22] = 6.91, p = 0.015) than shapes (F [1, 34] < 1, p = 0.349) and for individuals in the local group (F [1, 26] = 12.46, p < 0.01) as opposed to the global group (F [1, 30] < 1, p = 0.499). This level of interaction at the start of the discrimination task suggests a degree of caution will be necessary when interpreting discrimination difference scores.

Figure 10 shows discrimination difference scores split by level of processing. Global processing was not associated with any impairment in non-linear learning; individuals showing global processing showed strong learning regardless of discrimination task. In contrast, local processing was associated with impaired non-linear discrimination learning. Local processing was associated with weaker non-linear discrimination learning for both low and high neuroticism groups.

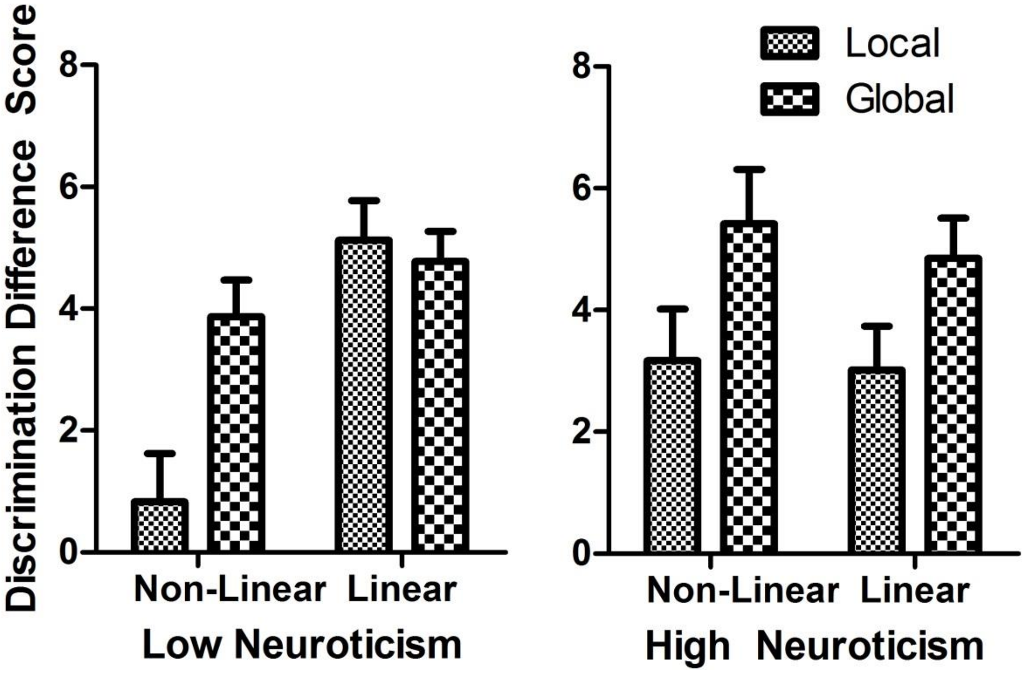


Figure 10: Discrimination Difference Scores, Experiment 3; split by Neuroticism score.

To assess the association between level of processing and discrimination learning, a 2x2x2x2 way ANOVA was conducted on discrimination difference scores, considering the factors of discrimination (linear vs. non-linear), stimulus type (shape vs. word), neuroticism group (low vs. high) and level of processing (local vs. global). Participants showed stronger discrimination learning with the linear than non-linear discrimination, (F [1, 56] = 4.95, p = 0.03). As observed in Experiment 1, there was a significant interaction between neuroticism group and discrimination (F [1, 56] = 9.55, p < 0.01). As observed in Experiment 1, there was a main effect of discrimination for the low neuroticism group (F [1, 29] = 20.22, p < 0.001), with a greater increase in discrimination over training in the linear than non-linear condition, and no main effect of discrimination for the high neuroticism group (F [1, 56] < 1, p = 0.595).

There was a significant interaction between level of processing and discrimination (F [1, 56] = 5.64, p = 0.021). Global processing was associated with stronger discrimination learning than local processing (F [1, 56] = 6.05, p = 0.017). However, there were significant interactions between discrimination task and neuroticism group (F [1, 56] = 9.55, p < 0.01) and level of processing (F [1, 56] = 5.64, P = 0.021).

Stimulus type did not appear to influence discrimination learning or interact with other factors influencing learning. There was no significant main effect of stimulus type (F [1, 56] < 1, p = 0.764) and no significant interactions with stimulus type (Maximum F [1, 56] = 1.48, p = 0.228).

Post hoc analysis indicated that there was a significant main effect of discrimination for individuals adopting local processing (F [1, 26] = 8.43, p < 0.01) but not for individuals adopting global processing (F [1, 30] < 1, p = 0.905). For individuals showing local processing there was a significant interaction between discrimination task and neuroticism group (F [1, 26] = 8.75, p < 0.01). Analysis revealed an effect of discrimination task for individuals with low neuroticism scores and local processing (F [1, 12] = 21.30, p < 0.01) but not for individuals with high neuroticism scores and local processing (F [1, 14] < 1, p = 0.971). Local processing was associated with weak non-linear discrimination learning, relative to linear discrimination learning, but only for individuals with low neuroticism scores.

Individuals with low neuroticism scores found the linear discrimination task easier than the non-linear discrimination task when they adopted local processing. There was a significant interaction between discrimination task and level of processing (F [1, 29] = 11.27, p < 0.01); such that there was an effect of discrimination task for individuals showing local processing (F [1, 12] = 21.30, p < 0.01), but not for individuals showing global processing (F [1, 17] < 1, p = 0.342). The effect of level of processing was specific to the non-linear discrimination; local and global groups did not differ significantly in terms of overall discrimination learning (F [1, 29] = 1.23, p = 0.277).

Post hoc analysis (with Bonferroni correction applied to control for multiple comparisons, significance level is 0.025) indicated that participants with high neuroticism scores did not show an effect of discrimination (F [1, 27] < 1, p = 0.595) regardless of level of processing (F [1, 27] < 1, p = 0.632). Individuals with high neuroticism scores showed a trend towards a main effect of level of processing (F [1, 27] = 5.39, p = 0.028) with individuals adopting local processing showing weaker discrimination learning across both linear and non-linear tasks. It may be of interest however to notes that the high neuroticism group showed an effect of level of processing prior to discrimination training, such that the local group showed strong linear discrimination from the start of training. Without this effect, we would expect to see a greater change in linear discrimination over training, potentially bringing the change in linear discrimination towards the level observed for the global group. This would move the results towards those observed for the low neuroticism group, suggesting that, if both groups had shown the same performance at baseline, comparable effect of level of processing may have been observed between the low and high neuroticism group. This suggests that differences occurring on the basis of an interaction between level of processing and neuroticism may occur at very early stages of discrimination training.

CONTROLLING FOR WORKING MEMORY CAPACITY

Controlling for working memory capacity, as measured by digit span, by including digit span as a covariate in this analysis, did not change the interaction between discrimination and level of processing (F [1, 55] = 5.30, p = 0.025). Analysis continued to reveal stronger discrimination learning for individuals adopting global processing as opposed to local processing (F [1, 55] = 5.78, p = 0.020). Further, there remained a significant interaction between discrimination task and neuroticism group (F [1, 55] = 9.00, p < 0.01).

REGRESSION ANALYSIS

These effects were not dependent on the specific point (mean split) chosen to categorise participants into two groups. Regression analysis, reported in Table 7, revealed that global/local score accounted for a significant proportion of variance in the strength of non-linear discrimination learning. Inclusion of other variables in this model (neuroticism, stimulus type, working memory capacity or ability to engage in learning, as measured by linear discrimination difference score) did not increase the proportion of variance accounted for significantly. This analysis met assumptions for regression analysis. There was no perfect linear relationship between predictors (highest VIF = 1.12, VIF tolerance = 0.89). Variance of residual terms was constant (homoscedasticity) and residual terms were uncorrelated (Durbin-Watson test score = 1.923). Distribution of residuals was normal.

Table 7: Regression analysis for the relationship between global/local score and non-linear discrimination learning in Experiment 3.

	B	SE B	β
Step 1			
Constant	2.95	0.46	
Global/local score	0.18	0.07	0.31*
Step 2			
Constant	4.82	4.86	
Global/local score	0.18	0.73	0.30*
Neuroticism	0.03	0.05	0.08
Stimulus type	0.86	084	0.13
Digit span	-0.64	0.62	-0.13
Linear discrimination difference score	0.26	0.17	0.20

*Note: $R^2 = 0.09$ for Step 1, $\Delta R^2 = 0.15$ for Step 2 ($p = 0.424$). *$p < 0.05$*

SPECIFICITY OF EFFECT

Variance in discrimination learning was observed specifically with non-linear discrimination learning and was explained, to an extent, by individual differences in the tendency towards local or global processing specifically. Variance in discrimination difference score in the linear discrimination was relatively low (SEM = 0.32). Discrimination difference scores for the linear discrimination did not correlate significantly with global / local score (r = 0.16, p = 0.20), suggesting that performance on the Navon task related more specifically to the task requirements of a non-linear than a linear discrimination.

Further it would appear to be performance on this aspect of the Navon task specifically that was associated with learning in the non-linear discrimination. Global/local score was a better predictor of non-linear discrimination difference score than other aspects of performance on the Navon task. For instance, in the Navon task participants completed congruent and incongruent trials, allowing calculation of how much faster participants were responding to congruent trials than incongruent trials (regardless of whether they were responding to a local or a global target). This calculation gives a congruent / incongruent score. This accounted for less than 3% of variance in the non-linear discrimination difference score. This was not significant (F [1, 62] = 1.58, p = 0.214).

3.1.3 DISCUSSION

This experiment aimed to assess whether a tendency towards processing specific details, as measured by the Navon task, was associated with an ability to solve a non-linear discrimination. The results presented here demonstrate considerable individual difference in the ability to solve a non-linear discrimination in absolute terms and relative to the limited individual difference in ability to solve a linear discrimination. This variation in the ability to solve a non-linear discrimination does not seem to be explained simply in terms of working memory capacity or general ability to learn. The results suggest that global processing, as measured by a global interference effect in the Navon task, was associated with ability to solve non-linear discrimination problems. In contrast, local processing, as measured by a local interference effect in the Navon task, was associated with impaired ability to learn a non-linear discrimination. This suggests that level of processing may account for a proportion of the observed variance in the ability to learn a non-linear discrimination. It would appear to be level of processing specifically that is associated with non-linear discrimination learning and not other aspects of perceptual processing measured by the Navon task, such as, a tendency to be distracted by incongruent information regardless of whether it is presented locally or globally.

This effect was only observed in individuals with low neuroticism scores. Tendency towards local processing was not associated with neuroticism score. As such, it is unlikely that variation in tendency towards processing specific details could account for the association between neuroticism score and learning, observed in Experiments 1 and 2.

3.2 EXPERIMENT 4

Experiment 3 found a tendency towards local processing to be associated with an impaired ability to learn a non-linear discrimination in individuals with low neuroticism scores. As such the experiment identified that individual differences in a dispositional factor related to the ability to engage in non-linear discrimination learning. The following experiments test whether the relationship is static, or whether experience can have a similar influence on ability to engage in non-linear learning.

Experience finding target letters presented at different levels of the hierarchically arranged stimuli can influence later performance in perceptual tasks. For instance, detection of a target at the global level is improved if the target is also presented at the global level in the preceding trial. Similarly, with targets presented at the local level improving later detection of targets presented at the local level (Filoteo, Friedrich, & Stricker, 2001; Lamb & Yund, 1996; Shedden, Marsman, Paul, & Nelson, 2003). This effect appears to be automatic and outside of voluntary control (Lamb, London, Pond, & Whitt, 1998; Ward, 1982) and is greatest when the target level is kept constant across a whole block of trials (Hubner, 2000; Lamb et al., 1998).

The effect of enhancing recognition at a certain level by providing experience finding targets at that level translates across tasks. Experience identifying global targets in the Navon task, enhances recognition of faces (Gao, Flevaris, Robertson, & Bentin, 2011; Macrae & Lewis, 2002; Perfect, 2003), a task acknowledged to be dependent on global or configural processing (Bartlett & Searcy, 1993; Diamond & Carey, 1986; Leder & Bruce, 1998, 2000; Maurer et al., 2002; Tanaka & Farah, 1993; Tanaka, Kiefer, &

Bukach, 2004; Tanaka & Sengco, 1997; Young et al., 1987). Providing experience identifying local targets impairs the recognition of faces (Macrae & Lewis, 2002; Perfect, 2003) but enhances recognition of features (Weston & Perfect, 2005). The effect has been documented across modalities; experience identifying global or local targets in one modality affects processing in other modalities (Forster, 2011).

These experiments demonstrate that tendency towards global processing can be manipulated with experience. Therefore, it is expected that providing participants with extended experience identifying targets at one or other level in hierarchically arranged Navon stimuli may influence their tendency to process compounds as separate stimuli or distinct configurations. If experience identifying global targets increases the tendency to process distinct configurations, then such training should enhance ability to learn a non-linear discrimination. In contrast, if experience identifying local targets decreases the tendency to process distinct configurations, such experience should impair ability to learn a non-linear discrimination.

Experiment 3 identified that while level of processing was unlikely to account for the association between neuroticism score and strong non-linear discrimination learning, neuroticism interacted with the relationship between level of processing and non-linear discrimination learning. To help understand this interaction further this experiment considered the influence of experience upon learning for low and high neuroticism groups separately.

3.2.1 METHOD

3.2.1.1 PARTICIPANTS

Sixty eight university students participated for course credit or were paid £5 for their participation. Forty eight participants were female. Twenty participants were male. Average age was 20.34 (3.13) years. Average digit span was 7.66 (0.53) digits. Average neuroticism score was 16.71 (7.30). Thirty nine participants completed global training. Twenty nine participants completed local training. The two training groups did not differ significantly in age (t [66] <1, p = 0.865), digit span (t [66] <1, p = 0.750), gender (t [66] <1, p = 0.780), or neuroticism score (t [66] <1, p = 0.711).

3.2.1.2 APPARATUS AND MATERIALS

Participants completed the digit span assessment (Lezak, 1995), the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995) and the negative patterning task, as described in Experiment 1. All participants completed the Navon task, adapted for training. The stimuli used in the Navon training task were the same as those used in Experiment 3.

3.2.1.3 PROCEDURE

Participants completed tasks in the following order; digit span, NEO-PI-R, Navon training task then the learning task. The procedure for the Navon training was similar to that used in the Navon test in Experiment 3, except, participants in the global training condition were asked to identify the large letter on all trials while participants in the local training condition were asked to identify the small letter on all trials. The negative patterning discrimination was completed as described in Experiment 1.

3.2.2 RESULTS

Analysis of the negative patterning task was conducted as described in Experiments 1 and 3. As described in Experiment 1, individuals who were unable to solve the linear discrimination were removed from analysis. This excluded 1 participant from the local pre-training group, who at the end of training continued to rate stimuli paired with the outcome as less predictive of the outcome than stimuli paired with no outcome.

As this experiment tested the effect of pre-training on the Navon task on performance learning a non-linear discrimination, it was important that participants completed the pre-training successfully. Errors made on the Navon task were measured; on average participants made 6.96 (5.33) errors. Participants with a high error rate (2 times the standard deviation above the mean) were excluded. This excluded one participant from each pre-training group. This left 15 participants in the local training group and 24 participants in the global training group. Following these exclusions the groups did not differ in age (t [63] < 1, p = 0.884), gender (t [63] < 1, p = 0.550) or working memory capacity, as measured by digit span (t [63] < 1, p = 0.712).

All participants showed a pattern of learning expected following the training. Figure 11 shows judgements of outcome likelihood through training, indicating, that change in judgements tracked the trained contingencies. A 2x2x2x2X2 way ANOVA was conducted on judgements of outcome likelihood with the factors of; predicted outcome (outcome vs. no outcome), discrimination (linear vs. non-linear), trial block (first vs. last), neuroticism group (low vs. high) and pre-training (local vs. global). There was a significant interaction between predicted outcome and trials (F [1, 61] = 113.67, $p < 0.001$) with participants’ judgements of outcome likelihood increasing over training for stimuli predictive of outcome, and decreasing over training for stimuli predictive of no outcome. Participant groups did not differ in their overall capacity to learn; there was no significant three way interaction between predicted outcome, trial and pre-training condition (F [1, 61] < 1, $p = 0.735$), or neuroticism group (F [1, 61] < 1, $p = 0.452$) and there was no significant four way interaction (F [1, 61] < 1, $p = 0.959$).

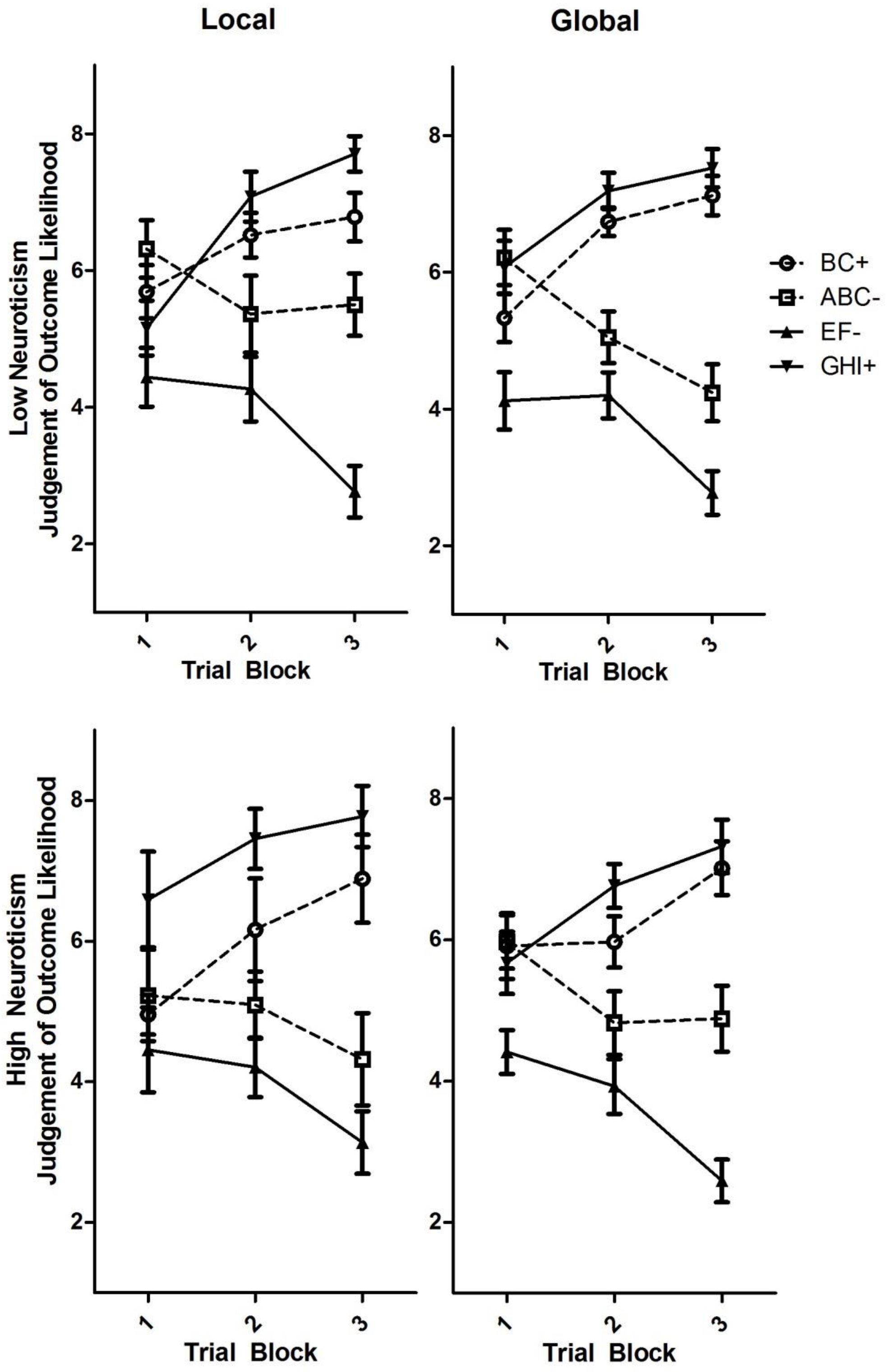


Figure 11: Judgements of the likelihood of the outcome occurring for negative patterning training in Experiment 4, split by pre-training; local (left), global (right) and neuroticism group; low neuroticism (top), high neuroticism (bottom).

Participants' judgements of the likelihood of the outcome occurring were used to calculate discrimination scores, as described in Experiments 1 and 3. A 2x2x2 way ANOVA was conducted on discrimination scores on the first trial block of training to test whether group differences were present prior to training. The analysis considered the factors of discrimination (linear vs. non-linear) neuroticism group (low vs. high) and pre-training (local vs. global). On the first trial block of training, though participants showed significantly higher discrimination scores in the linear than the non-linear discrimination (F [1, 61] = 20.14, $p < 0.001$), there was no significant main effect of pre-training (F [1, 61] < 1, $p = 0.862$) and no significant interaction between discrimination and pre-training (F [1, 61] = 1.68, $p = 0.819$). Further, there was no significant main effect of neuroticism group (F [1, 61] < 1, $p = 0.302$) and no significant interaction between discrimination and neuroticism group (F [1, 61] = 1.68, $p = 0.802$) or pre-training and neuroticism group (F [1, 61] < 1, $p = 0.374$). There was no significant three way in interaction between discrimination, neuroticism group and pre-training (F [1, 61] = 2.13, $p = 0.149$). This confirms that there were no baseline differences in discrimination between the pre-training groups.

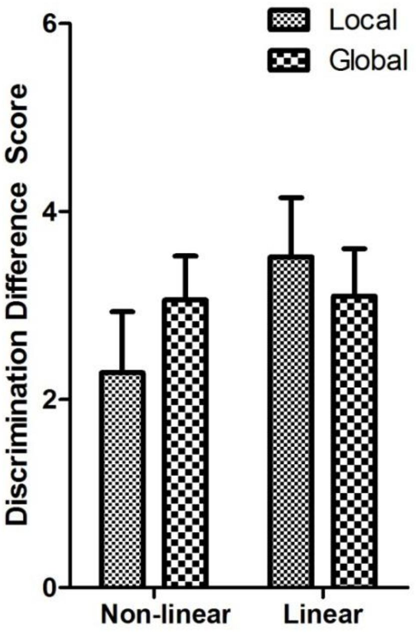


Figure 12: Discrimination difference scores split by Navon pre-training condition, Experiment 4.

Discrimination difference scores were calculated, as described in Experiments 1 and 3. Figure 12 shows discrimination difference scores split by pre-training task (global / local). It appears that, following local pre-training participants showed a tendency towards stronger learning in the linear than non-linear discrimination. In contrast, where participants received global pre-training there is no effect of discrimination task; here participants showed strong learning in both discriminations.

A 2x2x2 way ANOVA was conducted on discrimination difference scores. The analysis included the factors of discrimination task (linear vs. non-linear), neuroticism group (low vs. high) and pre-training (local vs. global pre-training). There was no significant main effect of discrimination task (F [1, 61] = 1.00, p = 0.320) and no significant interaction between discrimination task and level of processing (F [1, 61] < 1, p = 0.471) or neuroticism group (F [1, 61] < 1, p = 0.858). There was a significant interaction between neuroticism group, pre-training and discrimination task (F [1, 61] = 4.61, p = 0.036). To explore this interaction, analysis below considers the low and high neuroticism groups separately.

3.2.2.1 LOW NEUROTICISM

Thirty-seven participants with low neuroticism scores completed this task. Twenty-one of these participants completed global training, 16 completed local training. These groups did not differ in age (t [35] = 1.33, p = 0.192), working memory capacity (t [35] < 1, p = 0.934) or gender (t [35] < 1, p = 0.676).

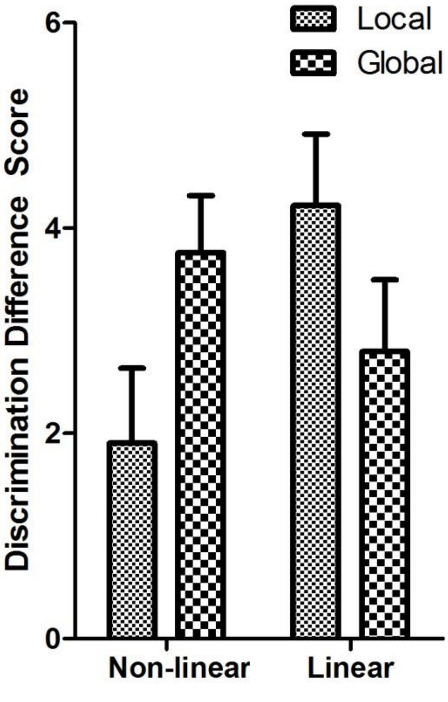


Figure 13: Discrimination difference scores split by Navon pre-training condition for the low neuroticism group, Experiment 4.

Figure 13 shows discrimination difference scores split by pre-training. Following local pre-training participants showed stronger learning in the linear than non-linear discrimination. In contrast, where participants received global pre-training there was minimal effect of discrimination task; here participants showed strong learning in both discriminations.

Analysis conducted on discrimination difference scores revealed no significant main effect of discrimination task (F [1, 35] = 1.29, p = 0.264) but there was a significant interaction between pre-training and discrimination task (F [1, 35] = 7.63, p < 0.01). Post hoc analysis (with Bonferroni correction applied to control for multiple comparisons, significance level is 0.025) indicated that participants receiving global pre-training showed no significant difference in their ability to learn the two discriminations (F [1, 20] = 1.92, p = 0.181). Participants receiving local pre-training showed a trend towards stronger learning with the linear discrimination than the non-linear discrimination (F [1, 15] = 5.26, p = 0.037).

3.2.2.2 HIGH NEUROTICISM

Twenty-eight participants with high neuroticism scores completed this task. Seventeen of these participants completed global training, 11 completed local training. These groups did not differ in age (t [26] = 1.36, p = 0.185), working memory capacity (t [26] < 1, p = 0.450) or gender (t [26] < 1, p = 0.545).

Figure 14 shows discrimination difference scores over training. This suggests that, in contrast with the effect of pre-training upon individuals with low neuroticism scores, for individuals with high neuroticism scores, local pre-training did not influence ability to solve a non-linear problem.

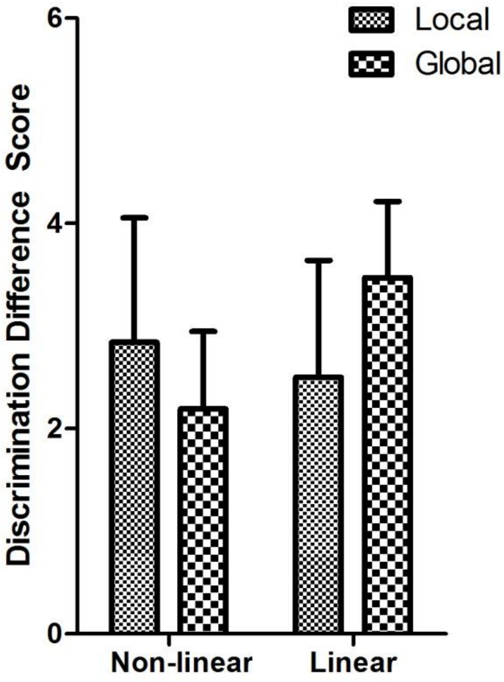


Figure 14: Discrimination difference scores split by Navon pre-training for individuals with high neuroticism scores in Experiment 4.

Analysis conducted on discrimination difference scores did not reveal a main effect of discrimination (F [1, 26] < 1, p = 0.661), or a significant interaction between pre-training and discrimination (F [1, 26] < 1, p = 0.450). This indicates that for the high neuroticism group, pre-training did not have a significant influence upon discrimination learning.

3.2.3 DISCUSSION

This experiment tested whether experience finding targets presented at a local or global level influenced ability to solve a non-linear discrimination. Experience identifying targets presented at a global level facilitated non-linear discrimination learning relative to experience identifying targets presented at a local level. Experience identifying targets presented at a global level has previously been shown to facilitate recognition of objects processed configurally, while experience identifying targets presented at a local has been shown to impair such recognition (Gao et al., 2011; Macrae & Lewis, 2002; Perfect, 2003). The results of this experiment indicate that recent experience attending to local or global information may influence associative discrimination learning. Experience identifying targets presented at a local level was related to a weak ability to solve a non-linear discrimination, relative to ability to solve a linear discrimination. Experience identifying targets presented at a global level was associated with ability to solve both a linear and non-linear discrimination.

The influence of experience interacted with personality. For individuals with low neuroticism scores, local pre-training limited ability to learn about stimulus configurations relative global pre-training. For individuals with higher neuroticism scores, the influence of experience was less clear; experience did not appear to have a systematic influence upon learning for the high neuroticism group.

3.3 GENERAL DISCUSSION

The aim of this study was to investigate the contribution of tendency towards processing specific details to individual difference in the ability to learn about combinations of stimuli as configurations distinct from their separate constituent stimuli. As such the experiments tested whether shifts in attention associated with stress were associated with changes in ability to engage in non-linear discrimination learning. Analysis indicated considerable individual difference in the ability to learn a non-linear discrimination.

Non-linear discriminations require individuals to learn that the co-occurrence of stimuli predicts a different outcome to that predicted by any of the constituent stimuli independently. While working memory capacity did not account for variation in non-linear discrimination learning, dispositional tendency towards processing specific details contributed significantly to variance in the ability to learn a non-linear discrimination. Further, experience identifying targets presented at a global or local level had a similar influence upon learning.

The finding of individual differences in non-linear discrimination learning is consistent with previous research (i.e., Shanks & Darby, 1998) and the results expand upon observations of variability in linear associative learning (Kaufman et al., 2009). As with more basic linear learning, individuals differ in their ability to engage in non-linear learning. In the experiments presented here, analysis of participants' learning used linear discrimination learning as a baseline and as such the results identify individual differences in non-linear discrimination learning above and beyond variability that may have occurred in linear discrimination learning. As such, these studies suggest that there may be considerably more variation in ability to learn a non-linear, as compared to a linear discrimination.

Shanks and Darby (1998) found rule-based as opposed to feature-based generalisation to be associated with strong non-linear discrimination. In general, studies exploring the influence of perceptual properties on learning have observed separable or multimodal stimuli, where separate components of compound stimuli are readily discernible, to be associated with more limited non-linear learning. In line with this, the experiments presented here suggest that the tendency to process the specific details as opposed to global configurations is associated with limited non-linear learning. Relating this to the Shanks and Darby (1998) experiment, suggests that rule base generalisation may require global processing, where the configurations as opposed to the specific components of the configurations are processed.

Experiment 4 demonstrated just how flexible learning might be. Exposure to different levels of hierarchically arranged information influenced later capacity to learn a non-linear discrimination. This hierarchal arrangement of information is pervasive. Consider a car; the shape and colour of the car are global levels of information whereas the number plate or shape of the headlights would, relatively, be local level information. We may expect that spending prolonged periods of time focussing on information presented at one or other level would have a substantial, though possibly short term, impact upon subsequent capacity to learn non-linear discriminations. This degree of flexibility makes it even more important for models of associative learning to be able to account for variability in non-linear learning.

As discussed in Chapter 1, there are models of learning which allow for flexibility. For example, the replacement parameter “r” introduced to the Replaced Elements Model allows variation in the extent to which compounds are represented as similar to their constituent stimuli (Wagner, 2003). The Replaced Elements Model conceives of stimuli as represented by multiple features or elements. Representation of certain elements will depend on the context of stimulus presentation. The replacement parameter “r” stipulates the proportion of context dependent elements that are replaced (Wagner, 2003). As the proportion of elements replaced increases, the representation activated when stimuli co-occur becomes less similar to the representations activated when the stimuli are presented separately. This shift should allow the co-occurrence of stimuli to be treated as a distinct combination, facilitating non-linear learning. This flexibility is based upon the premise of varying ability to discriminate, or differentiate, separate stimuli from the configuration in which they are presented.

Kinder and Lachnit (2003) introduced a discriminability parameter into Pearce’s configural model of learning to achieve a similar effect. The discriminability parameter allows the perceived similarity between stimuli and compounds to be altered, affecting the extent to which generalisation of associative strength is predicted. The model assumes that as it becomes harder to identify constituent stimuli within compounds, the discriminability parameter decreases, reducing the perceived similarity between compounds and constituent stimuli (Kinder & Lachnit, 2003). This posits a reduction in generalisation of associative strength that would facilitate non-linear discrimination learning.

Both of these accounts of flexibility focus upon changing the ability to discriminate separate stimuli from the compound in which they were presented. In allowing for learning with distinct compound stimuli to be modelled, the Replaced Elements Model stipulates that the features of the stimuli sampled when presented in compound will be different to the features sampled when those stimuli are presented separately. This approach may be effective when stimuli interact such that stimuli are perceived differently when presented in compound. Though the stimuli used in the current experiments were unimodal, they varied along a separable dimension. As such, presenting multiple stimuli on the same trial (i.e., triangles and squares) should have had minimal impact on ability to identify any individual stimulus (i.e., triangles). The Replaced Elements approach to account for the individual differences observed in discrimination learning would suggest that good discrimination learning in individuals showing global processing occurred because individuals were less able to identify a separate stimulus (i.e., triangles) when combinations of stimuli (i.e., triangles and squares) were presented. Specifically, though individuals showing a tendency towards global or local processing would be expected to have sampled the same number of features, the features sampled would not be the same. This seems improbable. Further, though it is conceivable for there to be more scope for perceptual representations of shape stimuli to interact than word stimuli, the analysis presented in Experiments 1 and 3 revealed no interaction with stimulus type. This raises further questions about the use of something like the Replaced Elements Model to account for the results presented here, as tendency towards processing specific details influenced discrimination learning regardless of the stimuli learnt about.

Variation in discrimination learning can be considered from a different perspective. Differences in the number of stimuli that are perceived or attended to; that is a limit on the sampling capacity may account for the association between the tendency to process specific details and limited ability to engage in non-linear discrimination learning. Sampling capacity here refers to the number of stimulus features that can be sampled on a given trial. To learn about and respond to the co-occurrence of stimuli as a distinct combination, it is reasonable to assume that features of each of the co-occurring stimuli must be sampled simultaneously, such that any given sample needs to contain features of each stimulus. Variation in sampling capacity should produce variation in the extent to which features of co-occurring stimuli can be sampled and as such result in variation in the ability to represent and learn about the distinct combinations of stimuli, required to learn a non-linear discrimination.

Many contemporary models of associative learning incorporate a limit to sampling capacity (e.g., McLaren & Mackintosh, 2000; Pearce, 1987, 1994). Stimulus sampling theory postulated that only a subset of features that might potentially be activated by the presentation of a given stimulus will actually be sampled on any given trial (Estes, 1955). Though Estes (1955) assumed sampling to be essentially random, contemporary theories have assumed that sampling occurs on the basis of intensity such that varying the perceived intensity of stimuli influences how stimuli are sampled and thus influences learning (e.g., Pearce, 1987).

Though relative variation in sampling has been widely considered (e.g., Pearce, 1987), to my knowledge variation in absolute sampling capacity has not. It is plausible that individuals might differ in the number of stimulus features they sample simultaneously or that the same individual might increase or decrease the number of items sampled, through practice, attention or other motivational or dispositional factors. Changing the absolute number of stimulus features sampled is predicted to have a specific and systematic impact on learning. As the number of stimulus features sampled decreases the probability of simultaneously sampling features from different co-occurring stimuli will be reduced, limiting ability to encode conjunctions of multiple stimuli. For instance, in the case of non-linear learning, where participants are required to learn that combinations of stimuli are predictive of outcomes independent from the outcomes associated with their constituent stimuli, reducing the number of stimuli features sampled on a given trial should impair ability to encode and learn about the co-occurrence of stimuli as a distinct configuration. Reduced ability to encode and learn about configurations of stimuli should reduce capacity to learn non-linear discriminations but have no impact upon ability to learn linear discriminations, which depend only on the one-to-one correspondence between separate stimuli and the outcomes they predict.

Capacity to encode a configuration of stimuli, when multiple stimuli co-occur is assumed to be dependent on whether features from each stimulus are sampled simultaneously. As the number of features sampled is reduced, the probability of this occurring will decrease. For instance, let us take an example of attempting to learn about the configuration of three equally salient stimuli, **A**, **B**, and **C**. Let us assume that each stimulus is characterised by 10 features ($\mathbf{A}_1$, $\mathbf{A}_2$, $\mathbf{A}_3$… $\mathbf{B}_1$, $\mathbf{B}_2$… etc.), such that there are 30 features in total. Encoding the conjunction of **A**, **B** and **C**, is dependent upon at least one feature of each stimulus being sampled simultaneously. In this case, if 10 features are sampled, there is a 98% chance of this happening. This is calculated as the number of ways of selecting three stimuli comprised 10 features divided by total number of ways of selecting three stimuli from 30 features, as shown in Equation 4.

Equation 4

$$P.represent\ config = 1 - \left(\frac{\left(\left(\frac{(n_A + n_B)!}{S!\left((n_A + n_B) - S\right)!} \right) + \left(\frac{(n_A + n_c)!}{S!\left((n_A + n_c) - S\right)!} \right) + \left(\frac{(n_B + n_C)!}{S!\left((n_B + n_C) - S\right)!} \right) \right)}{\left(\frac{S!}{k_t!\,(S - k_t)!} \right)} \right)$$

Where s is the total number of features sampled (here 10); k_t is the total number of features possible to sample (here 30); n_a, n_b and n_c are the number of features representing stimulus **A**, **B** and **C** respectively. The probability of representing a configuration if 10 features are sampled is thus 98%. However, if a smaller sample is taken from the same stimuli, i.e., capacity is constrained to 5, the likelihood of representing the conjunction of three stimuli on any given trial falls to 67%.

As the number of features sampled decreases the probability of encoding a configuration of co-occurring stimuli will be reduced. Figure 15 illustrates the relation between sample size and probability of sampling a configuration for a set of 3 stimuli, each represented by ten features.

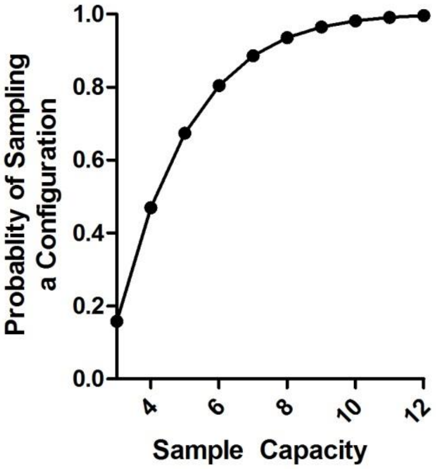
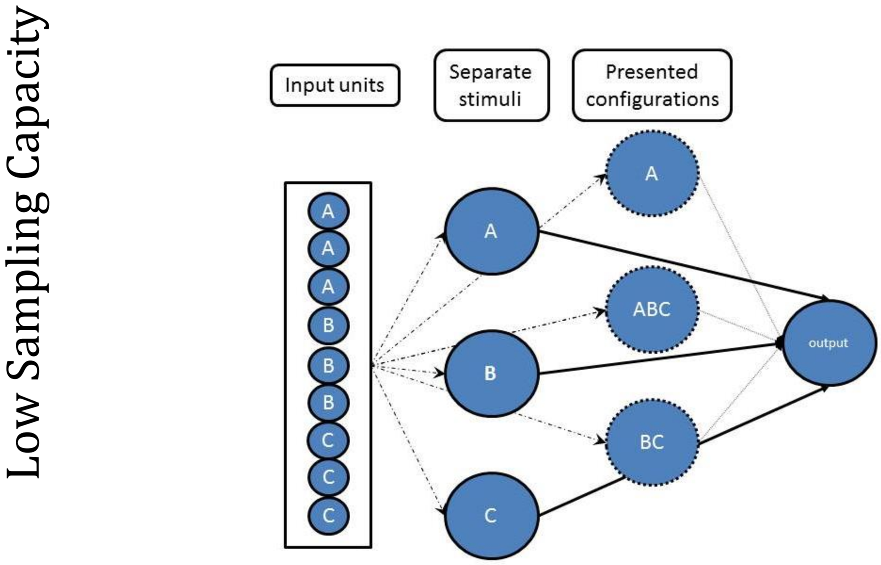


Figure 15: Relationship between sample capacity and probability of sampling a configuration, for a set of 3 stimuli, each represented by ten features, as calculated in Equation 4.

The impact of variation in sampling capacity can be modelled by adjusting the existing configural model of learning (Pearce, 1987). The configural model of learning allows learning with configural units, allowing learning with the complete configurations of the stimuli actually presented (i.e., **A**, **BC** and **ABC**). The results presented here suggest that when individuals tend towards local processing, suggesting constrained sampling, they learn about the separate stimuli and not the configurations.

Figure 16: Cartoon showing connection of units for the model proposed. This model allows for flexibility in change of associative strength and generalisation. For simplicity, the diagrams separate flexibility in change in associative strength from flexibility in generalisation, to show these two factors in separate diagrams.

Weight of association between separate stimuli and outcome is high. Weight of association between presented configurations and outcomes is low.



Weight of association between separate stimuli and outcome is low. Weight of association between presented configurations and outcomes is high.

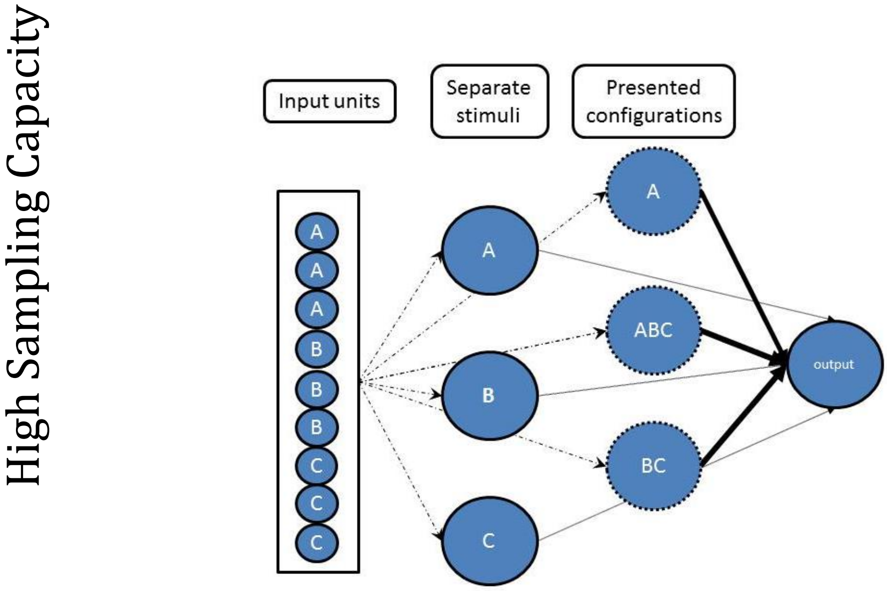
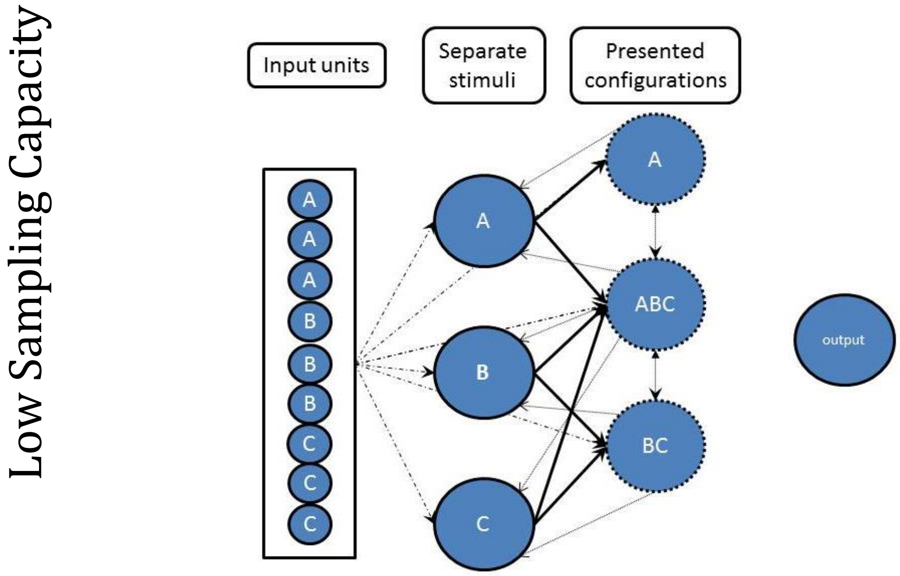


Figure 16a; Change is associative strength, shown by the weight of the lines depicted. The top panel shows weights of association with outcome for a low f value. The bottom panel shows weights of association with outcome for a high f value. Change in associative strength varies such that when sampling capacity is limited, the model follows elemental learning, with higher change in associative strength for separate elements than presented configurations. When sampling capacity is not limited, the model follows configural learning with higher change in associative strength for presented configurations than separate elements.

Generalisation from separate stimuli to presented configurations is high. Generalisation from presented configurations to other configurations and separate stimuli is low.



Generalisation from separate stimuli to presented configurations is low. Generalisation from presented configurations to other configurations and separate stimuli is high.

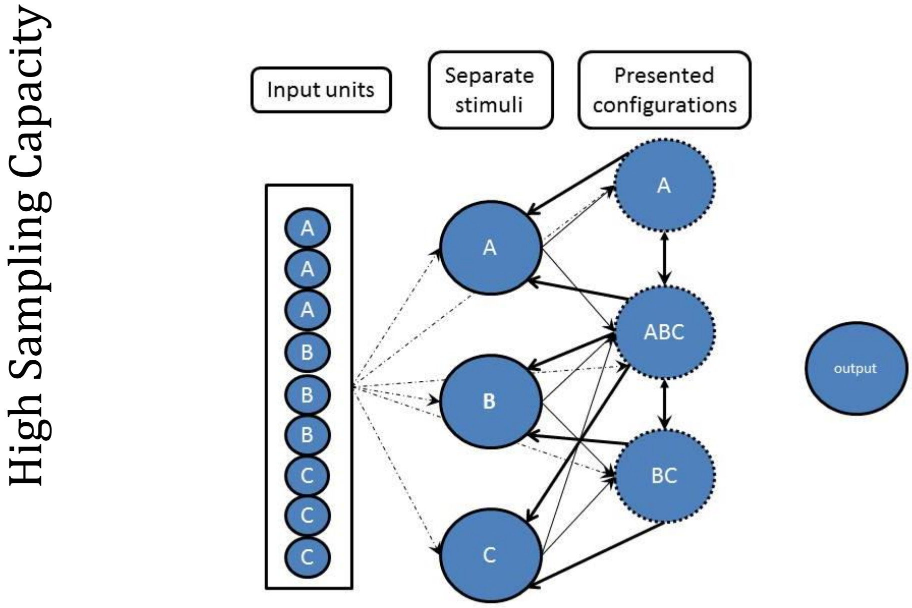


Figure 16b; Generalisation changes with sampling capacity. The top panel shows direction and strength of generalisation for a low f value and the bottom panel shows direction strength of generalisation for a high f value. When sampling capacity is limited generalisation will occur between from separate stimuli to presented configurations, but not vice versa. When sampling capacity is not limited, the model allows for generalisation from presented configurations to separate stimuli and to other presented configurations.

COMBINING ELEMENTAL AND CONFIGURAL MECHANISMS

An account for this flexibility can be approached from the perspective of variation in sampling of input units. To allow for such variation, we can adapt the configural model so that it can account for how learning might proceed if complete configurations have not been sampled. This is shown in Figure 16. To do this requires two sets of nodes activated by input; separate stimuli and presented configurations. Both sets of nodes can form associations with outcomes and generalisation can occur between all nodes. When sampling capacity is sufficient to give a high probability of sampling a configuration, learning and generalisation will be weighted towards the presented configurations, allowing learning to occur with the distinct configuration.

When sampling capacity is constrained, such that there is a low probability of sampling a configuration, learning and generalisation will be weighted towards separate stimuli. This does not preclude responding to the configuration; associative strength may generalise from separate stimuli to presented configurations. Learning with presented configurations, as a unit distinct from the separate stimuli, will be reduced.

For the model to account effectively for flexibility between learning about separate stimuli and configurations, learning and generalisation need to be treated differently for separate stimuli and for configurations. Reflecting assumptions of elemental models of learning (i.e., Rescorla & Wagner, 1972), learning with separate stimuli is governed by a summed error term, such that change in excitatory or inhibitory strength for a separate stimulus will be given by Equation 5.

Equation 5

$$\Delta \mathrm{E}_{\mathrm{A}} = \alpha\, \mathrm{B}\, (\lambda - \mathrm{V}_{\mathrm{t}})$$

Where α represents the salience of the conditioned stimulus and β represents the salience of the outcome or unconditioned stimulus. V_t represents the total associative strength of all stimuli present on that trial. As such, when this model is following an elemental mechanism of learning, while training **A**+ and **BC**+ would allow the associative strength of **A** and **BC** reach the same level, the associative strength of **B** and **C** separately should be half that of **A**.

Generalisation from separate stimuli to presented configurations should also follow elemental assumptions (i.e., Rescorla & Wagner, 1972), such that the associative strength of a presented configuration (i.e., **BC**) should be, the sum of the total associative strength of each constituent stimulus, as given by Equation 6.

Equation 6

$$V_{BC} = V_B + V_C$$

In contrast, learning with presented configurations should follow configural assumptions of learning (i.e., Pearce, 1987) such that change in excitatory (E) or inhibitory (I) strength of a presented configuration is determined by the acquired associative strength of that configuration, as given by Equation 7. If λ is less than 0, changes in the inhibitory strength of the CS, $\Delta\mathrm{I}_{\mathbf{BC}}$, will occur to a similar magnitude.

Equation 7

$$\Delta\mathrm{E}_{\mathbf{BC}} = \mathrm{B}\,(\lambda - \mathrm{V}_{\mathbf{BC}})$$

As specified in Pearce’s (1987) configural model of learning the associative strength of a separate stimulus or presented configuration is given by the sum of the excitatory (E) or inhibitory (I) strength accrued by that unit and the excitatory (e) or inhibitory (i) strength generalising to the unit from similar separate stimuli (i.e., the stimuli composing the presented configuration) and other similar presented configurations, as given by Equation 8.

Equation 8

$$V_{BC} = E_{BC} + e_{BC} - \left(I_{BC} + i_{BC}\right)$$

Where E represents excitatory strength, I inhibitory strength, e generalised excitatory strength and i generalised inhibitory strength.

For presented configurations there are two sources of generalised excitatory or inhibitory strength; generalisation from separate stimuli and generalisation from similar configurations. As such generalised excitatory or inhibitory strength is given by the sum of excitatory or inhibitory strength of separate stimuli composing the presented configuration and the sum of excitatory or inhibitory strength of similar presented configurations, given by Equation 9.

Equation 9

$$e_{BC} = \left(\sum_{j=1}^{n} elem\left(\mathrm{E_j}\right)\right) + \left(\sum_{j=1}^{n} config\left({}_{j}\mathrm{S}_{\mathbf{BC}} \times \mathrm{E_j} \right)\right)$$

The total excitatory or inhibitory strength of constituent stimuli should generalise from separate stimuli to presented configurations. However, following assumptions of configural learning the strength of generalisation between presented configurations and from presented configurations to separate stimuli should be determined by similarity (Pearce, 1987). Similarity is calculated as the proportion of features that presented configuration share in common, as given by Equation 10.

Equation 10

$$jS_A = \frac{Pcom}{P\sum_J} \times \frac{Pcom}{P\sum_a}$$

Where the value of $Pcom$ is determined by the perceived intensity (p) of the stimuli that are common between presented configurations. The values of $P\sum_J$ and $P\sum_a$ are set according to the total perceived intensity of the stimulation on trials where **A** and J, respectively, are presented.

As with presented configurations, the associative strength of separate stimuli is dependent on the sum of a stimulus's own excitatory or inhibitory strength and the excitatory or inhibitory strength generalising to the stimulus, described by Equation 8. The excitatory or inhibitory strength generalising to the separate stimuli is given by Equation 11.

Equation 11

$$e_A = \sum_{j=1}^{n} config\,(\mathrm{jS_A} \times \mathrm{E_j})$$

INTRODUCING FLEXIBILITY INTO THE MODEL

To allow for flexibility between learning about separate stimuli or distinct configurations, two factors have to be adjusted; the rate of change of excitatory or inhibitory strength and the strength of generalisation. When sampling capacity is limited, learning will be constrained to the separate stimuli. As such, a change in the excitatory or inhibitory strength of the separate stimuli should be high while change in the excitatory or inhibitory strength of the presented configurations should be low.

The opposite pattern is expected if sampling capacity is greater, such that configurations of co-occurring stimuli can be sampled. Under these conditions, learning may occur with distinct configurations, such that change in the excitatory or inhibitory strength of the configurations should be high while change in the excitatory or inhibitory strength of the separate stimuli should be low. To facilitate this flexibility the parameter “f” can be added to the equations calculating change in excitatory strength for separate stimuli (Equation 12) and configurations (Equation 13); where “f” represents the probability of sampling a configuration, as calculated in Equation 4.

Equation 12

$$\Delta E_A = \alpha \, \beta \, (1 - f)(\lambda - V_t)$$

Equation 13

$$\Delta E_{\mathbf{BC}} = \beta \, f \, (\lambda - V_{\mathbf{BC}})$$

As described by Pearce’s (1987) configural model, change in excitatory strength influences excitatory and inhibitory strength such that where ΔE_A is positive, the change is accrued by excitatory strength E_A. Where ΔE_A is negative, instead of resulting in a decrement in the value of E_A, such a trial will result in the accumulation of inhibitory strength, I_A.

As sampling capacity increases, increasing ability to learn about distinct configurations, generalisation of excitatory and inhibitory strength should change. When learning about separate stimuli, associative strength should generalise from separate stimuli to configurations but not vice versa. When learning about distinct configurations, associative strength should generalise between configurations and from configurations to separate stimuli, to the extent that these events are similar. This shift in weight of generalisation can be accommodated again by incorporating the parameter “f.” As such, the excitatory or inhibitory strength generalising to separate stimuli would be given by Equation 14 while the excitatory or inhibitory strength generalising to presented configurations would be given by Equation 15.

Equation 14

$$e_A = \sum_{j=1}^{n} config\,(\mathrm{j}\mathrm{S}_{\mathrm{A}} \times \mathrm{E}_{\mathrm{j}} \times \mathrm{f})$$

Equation 15

$$e_{BC} = \left(\sum_{j=1}^{n} elem\left(\mathrm{E}_{\mathrm{j}} \times (1 - \mathrm{f})\right) \right) + \left(\sum_{j=1}^{n} config\left({}_{j}\mathrm{S}_{\mathbf{BC}} \times \mathrm{E}_{\mathrm{j}} \times \mathrm{f}\right) \right)$$

The magnitude of the parameter f reflects the probability of encoding a configuration, calculated from sampling capacity as illustrated in Equation 4. Where sampling capacity is constrained, the probability of encoding a configuration will be low and thus the parameter f will be low. Where sampling capacity is less constrained, the probability of encoding a configuration will be higher and thus the parameter f will be higher.

This modification of the configural model can predict the results observed in the experiments presented in this chapter. Figure 17 shows discrimination difference scores for linear and non-linear learning as described in the experiments presented here. Simulations for local processors, assuming constrained sampling capacity, have been run with f set to 0.2. Simulations for global processors, assuming less constrained sampling capacity, have been run with f set to 0.8. In these simulations, there is no difference between local and global processors when learning a linear discrimination. Learning a non-linear discrimination, local processors but not global processors, are severely impaired.

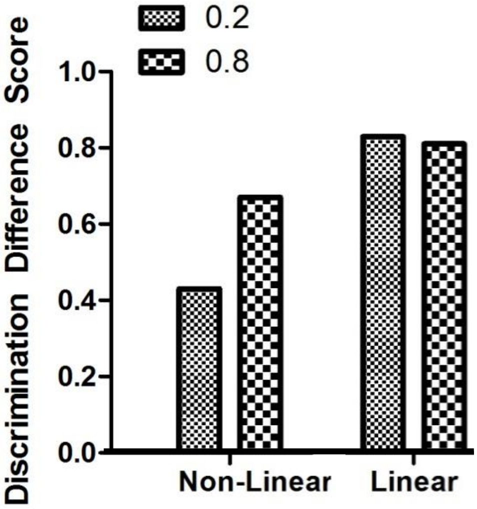


Figure 17: Simulated discrimination difference scores, as calculated with Equation 13 and Equation 14, for f = 0.2 (low probability of sampling a configuration) and f = 0.8 (high probability of sampling a configuration).

This model modifies existing accounts of learning to provide a way of predicting variation in learning arising due to differences in the initial processing of stimuli. It is possible both to learn about separate stimuli and distinct configurations. Greater sampling capacity may dispose individuals to be more likely to learn about distinct configurations. With an average sampling capacity, such that the parameter “f” is 0.5, individuals are expected to engage in learning with separate stimuli and distinct configurations.

It should be noted that though working memory capacity, as measured by a digit span assessment, did not correlate with non-linear discrimination learning or a tendency towards global processing, only one test of working memory was administered in the current study. Variation in working memory capacity was limited presumably due to the relatively homogenous sample (university students). It is possible that with a broader measure, working memory may be found to relate to sampling capacity, as the two concepts appear conceptually similar. Considering this relationship in further research may be beneficial.

The impact of stress upon information processing was discussed in Chapter 1. High emotional arousal is associated with a narrowing of attention to focus on specific details (Brown, 2003; Cavenett & Nixon, 2006; Christianson et al., 1991), which may be expected to reflect something like local processing, here associated with impaired non-linear discrimination learning. This would suggest stress to be associated with impairments in the ability to process combinations of stimuli as distinct and different from its constituent features. This finding contrasts with observations of improved binding of relevant information under situations of high arousal (Mather & Sutherland, 2011). It is possible that while a focus on specific details impairs ability to learn about combinations of stimuli, arousal improves binding of specific details. This may then facilitate ability to process combinations of stimuli. Indeed, in the experiments presented here learning about distinct combinations of information was not influenced by a tendency to focus on specific details for individuals with higher neuroticism scores. Further research into the interactions between stress, personality and learning may provide novel insight into why some people are more vulnerable to developing mental health problems following stressful experiences. To try to understand the relationship between neuroticism, local processing and learning further, Chapter 4 focuses on possible associations between neuroticism and the tendency to focus on specific details.

CHAPTER 4

4 PERCEPTUAL PROCESSING

There is considerable evidence suggesting that high anxious, emotional states cause attention to narrow (Easterbrook, 1959) and emotionally arousing stimuli, specifically negative stimuli, are encoded and subsequently remembered better than the peripheral, neutral information with which they are presented (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). While this been proposed to arise because a “narrowing” of attention (Easterbrook, 1959), others (e.g., Mather & Sutherland, 2011) suggest that attention here is object based (Scholl, 2001), so that stress enhances the priority of goal relevant information while diminishing that of goal irrelevant information (Levine & Edelstein, 2009). This change in attention tends to result in peripheral context information not being encoded, resulting in improved memory for relevant details coming at a cost to recall of peripheral details (e.g., Loftus et al., 1987). Indeed, it has been demonstrated that reinstating the context does not improve recall of arousing events, suggesting that context information is not initially encoded (Brown, 2003). As neuroticism is associated with chronic high distress (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004; Schneider, 2004; Uliaszek et al., 2010), these changes may account for strong non-linear learning observed in Experiments 1 and 2. Focusing attention upon goal relevant information may be expected to facilitate discrimination learning and reduced attention towards context information may be expected to reduce generalisation.

Changes in attention are not simply related to the intrinsic salience of stimuli presented. Rather, what we attend to appears to be influenced by a combination of the salience of stimuli and dispositional factors, such as level of arousal. Manipulating arousal directly biases attention towards relevant information at the cost to periphery information (Cavenett & Nixon, 2006). Manipulating mood appears to have similar effects, with negative mood inductions enhancing tendency to focus on specific details rather than global information (Basso et al., 1996; Gasper & Clore, 2002).

This is not just a state effect; individuals with Obsessive Compulsive Disorder, a condition associated with high levels of stress, also appear to show a bias towards focussing on the details, (Yovel et al., 2005); a “tendency to miss the forest for the trees” (Derryberry & Reed, 1994; Tyler & Tucker, 1982). This demonstrates that while contractions of attention are associated with acute changes in state such as stress and high emotional arousal, they may also associated with longer term conditions, such as OCD. Experiments 1 and 2 indicated that neuroticism is associated with strong non-linear learning. The results of Experiments 3 and 4 suggest that dispositional traits or states associated with a focus on specific details may be associated with impaired non-linear learning. A focus on specific details may reflect a reduction in the number of elements sampled simultaneously, reducing the probability of sampling a configuration of stimuli. While chronic distress, associated with neuroticism, may be expected to narrow attention, the findings from the first four experiments suggest that this relationship may not be straightforward.

The relationship between dysphoria, as measured by the BDI, neuroticism and the tendency to process specific details is explored through this chapter. To start to understand this relationship and what global/local processing tasks can tell us about neuroticism, I briefly review the literature on individual differences in perceptual processing. Much of this literature considers autism and the relation between autism and a tendency to process details rather than global configurations.

AUTISM AND MEASURING GLOBAL PROCESSING

Individuals with autism have been described as showing an “inability to experience wholes without full attention to the constituent parts” (Kanner, 1943). This detail focused processing style has been characterised as Weak Central Coherence (Happe & Frith, 2006); defined as an absence of the typically observed drive to process incoming information in terms of meaning and global form (Frith, 1989). This lack of bias to attend to global information is measured using the Navon task (Navon, 1977) and the Embedded Figures Task (Witkin et al., 1971). The Navon task, used in Experiments 3 and 4, tests performance in a global-local paradigm, assessing ability to identify targets presented at either the global or local level. The task is seen as a neutral assessment of processing bias (Brosnan, Scott, Fox, & Pye, 2004). In contrast, the Embedded Figures Task (EFT), originally developed to test field dependence (the extent to which context information governs identification of details; Witkin, 1950) assesses ability to focus on local details while ignoring peripheral, context information. Weak Central Coherence, or more specifically a shift in attention towards specific details, should enhance performance on the EFT.

While findings of altered performance on the Navon task, in individuals with autism, have been mixed, autism is consistently associated with improved performance on the Embedded Figures Task (Happe & Frith, 2006). The EFT measures time taken to locate and trace simple shapes embedded within a complex diagram. Unlike the Navon task, solving the EFT does not simply require a shift in attention towards specific details; good performance demands ability to bind local features together (Missler, 1986). Interestingly the influence of arousal upon processing has been proposed to enhance binding both of intrinsic features of single items and binding of separate items in memory when the association between the items has high priority (Hadley & Mackay, 2006; Mather & Sutherland, 2011). As such arousal may be expected to enhance performance on the EFT.

Autism has also been associated with enhanced performance on the Block Design task (Kohs, 1923) and local bias on the Rey Complex Figure Task (Osterrieth, 1944; Rey, 1941). The block design task (Kohs, 1923) requires participants to use shaded blocks to replicate complex designs, depicted in diagrams. The task requires complex images to be decomposed into relevant constituent features. Good performance, as seen in individuals with autism, is thought to demonstrate superior detail processing (Shah & Frith, 1993). The Rey Complex Figure Task (RCFT), like the Navon task, is a neutral task assessing the tendency to focus on the local details or the global picture. In this, open ended drawing task, participants are asked to copy a complex figure, which they then later draw from memory. Drawing strategy is used to assess global/local bias. Global bias is identified by individuals starting by drawing the overarching structure of the image. Local bias is identified by individuals starting by drawing the fine details.

Though these tasks are used to assess weak central coherence, there have been problems defining precisely what Weak Central Coherence means and what factors contribute to strong or limited performance on the tasks discussed above. Weak Central Coherence has been related to difficulty broadening the spread of visual attention, i.e., difficultly zooming out (Mann & Walker, 2003). However, whether narrow breadth of attention accurately captures Weak Central Coherence is debatable. For instance, individuals can show enhanced local processing while continuing to show intact global processing (Mottron & Burack, 2001). Rather than relating to a general change in breadth of attention, it has been argued that weak central coherence reflects problems with the configural relationships between elements, suggesting that limited processing of "inter-element" relationships could account for the failure to be influenced by context (Brosnan et al., 2004), as seen in the EFT.

MOOD AND MEASURING GLOBAL PROCESSING

Despite the relationship between mood, emotional arousal and breadth of attention (Basso et al., 1996; Fredrickson & Branigan, 2005; Gasper & Clore, 2002), hierarchical processing (i.e. tendency towards processing local or global stimuli) has received very little attention in depression research. Studies have looked at how attention in depression interacts with negative information in terms of heightened selectivity for negative information (Bradley et al., 1997; Gotlib et al., 2004; Koster, De Raedt, Goeleven, Franck, & Crombez, 2005; Mathews & MacLeod, 2005; Mogg et al., 1995) and problems shifting attention away from negative information (Harvey, 2004; Joormann, Yoon, & Zetsche, 2007). However, these studies in do not ask whether the basic processes of attention are disrupted in depression.

Reviewing the literature on cognitive markers for depression, a selection of studies that have incorporated tests associated of Weak Central Coherence into their battery of cognitive tasks, can be identified. The results of these studies are mixed. Unlike autism, depression has been associated with impaired performance on the block design task in some studies (Beblo, Baumann, Bogerts, Wallesch, & Herrmann, 1999; Gorlyn et al., 2006; Naismith et al., 2003), however, other studies have found no such association (Crews, Harrison, & Rhodes, 1999; Keilp et al., 2001). Studies using the RCFT as a measure of visual memory in general have observed no association between depression and task performance (Behnken et al., 2010; Deluca, Johnson, Beldowicz, & Natelson, 1995; Rohling, Green, Allen, & Iverson, 2002).

It is clear that depression is not associated with enhanced performance on these tasks. However, there is an informative mismatch between patterns of performance measured on the block design and RCFT. Local processing is associated with poor recall on the RCFT but enhanced performance on the block design task. As the two tasks are designed, good performance on one task should predict poor performance on the other task. Individuals with depression show impaired or normal performance on both of these tasks. As such, it is possible that studies of individuals with depression are influenced by general impairments in memory or attention and as such are not sensitive to biases in hierarchical processing. Performance in tasks such as the block design task is measured in terms of response time and these tasks demand sustained concentration. As depression is widely associated with slow performance and impaired concentration, these tasks may not be well designed to identify differences in hierarchical processing in individuals with depression. To identify underlying differences in hierarchical processing, potentially associated with depression, it may be useful to look at a non-clinical population at risk for depression; specifically, individuals with high BDI scores and individuals with high neuroticism scores.

This chapter presents experiments using two tasks to test the tendency towards processing specific details, the EFT and the Navon task, in individuals with high BDI scores and high levels of neuroticism. The first four experiments (Experiment 5 – 8) test associations between dysphoria, neuroticism and the tendency to focus on specific details. These experiments explore aspects of shifts in attention towards specific details, testing whether individual differ in their ability to prioritise goal relevant information or ignore contextual information. Expanding to look at other aspects of information processing influenced by stress, in Experiment 9, I use a feature search task to test whether neuroticism is associated with enhanced ability to identify conjunctions of features.

4.1 EXPERIMENT 5

The Embedded Figures Task (Witkin et al., 1971) was developed to test field dependency, assessing perception of objects in relation to their surroundings (Witkin, 1950). Today the task is used to test Weak Central Coherence (Jolliffe & BaronCohen, 1997). Witkin observed considerable individual difference in, what he termed, field dependency; that is, peoples' tendency to see parts within a larger whole (Witkin, 1950; Witkin & Goodenough, 1977; Witkin et al., 1954). While some individuals are able to process parts as independent units, for others, perception of the "part" is strongly influenced by the surrounding field; the context in which the "part" is presented (Witkin, 1950; Witkin et al., 1954). In requiring individuals to locate simple figures within a complex diagram, the EFT is assumed to measure capacity to overcome the context of a given field (Missler, 1986). Previous research suggests that females are more strongly influenced by the context than males, showing relatively poorer performance on this task (Witkin, 1949). The role of neuroticism in performance has also been explored; however, results have been mixed (Carter & Loo, 1979; Evans, 1967; Fine, 1972; Goggin et al., 1979).

Narrow breadth of attention or local processing may not be sufficient to enhance performance on this task. The task requires participants to perceive the structure of the simple form as a whole object and hold this in mind. As such, there is more to this task than simply requiring participants to focus on the local details while ignoring the global information. Negative emotional arousal, however, is not simply associated with narrow breadth of attention but is also associated with a tendency to prioritise goal relevant information (Levine & Edelstein, 2009) and enhanced binding of features of an object (Hadley & Mackay, 2006; Mather & Sutherland, 2011). These facets of negative emotional arousal suggest that low mood should be associated with enhanced performance on the EFT.

4.1.1 METHOD

4.1.1.1 PARTICIPANTS

Eighty eight university students participated for course credit or were paid £5 for their participation. Table 8 shows demographics for all participants. Participants were divided into three groups on the basis of a tertile split of BDI (low, middle and high), measured using the Beck Depression Inventory (Beck, Ward, Mendelson, & Erbaugh, 1961).

Average participant age was 20.83 (3.89) years. Age did not correlate significantly with BDI score (r = 0.09, p = 0.381). Average digit span was 7.02 (1.07) digits. There was a non-significant negative correlation between digit span and BDI score, such that individuals with higher BDI scores tended to have a lower digit span (r = -0.21, p = 0.055). Twenty five participants were male. Sixty three participants were female. Gender was not associated with any significant difference in BDI score (U (25, 63) = 761.00, p = 0.806).

Table 8: Demographics for participants in completing the EFT in Experiment 5, split by three BDI groups.

	BDI Group		
	Low	Middle	High
N	30	28	30
BDI Range	0 – 3	4 – 10	11 – 24
BDI score	1.13 (0.92)	6.38 (2.33)	15.58 (3.79)
Age, years	20.67 (3.82)	20.14 (2.61)	21.63 (4.82)

Digit span, digits recalled	7.30 (0.92)	7.04 (1.20)	6.73 (1.05)
Gender (male)	9	9	7

4.1.1.2 APPARATUS

All participants completed the digit span task (Lezak, 1995), the BDI (Beck, 1972) and the EFT (Witkin et al., 1971). The EFT was completed as a pen and paper task. The task consists of 18 problems split into two sections. Each page of the test booklet included only one problem. Each problem used a new complex figure. There are nine simple shapes displayed on the back page of test booklet. Each problem stipulated which one of the simple shapes should be located within the complex figure.

4.1.1.3 PROCEDURE

Participants completed the BDI between 48 hours and two weeks prior to the test session. At the test session participants completed tasks in the following order; BDI, EFT, digit span. Average BDI was calculated from the two test time points.

Embedded Figures Task

Participants were initially given two example problems. Participants were instructed to complete the problems in order and not to skip problems unless absolutely stuck. They were also instructed to trace only one simple shape in each problem. Participants were provided with an eraser for mistakes. The experimenter checked that participants understood the task requirements and had accurately completed the example problems before proceeding with the first section. Participants were allowed to flip to the back page, to check the simple shapes, as often as necessary. Participants had five minutes for each of the two sections. Number of problems accurately completed was scored and completion time was recorded.

4.1.2 RESULTS

Figure 18 shows total time to complete all 18 problems, split by group. The low BDI group took, on average, approximately one minute longer to complete the EFT than the high BDI group.

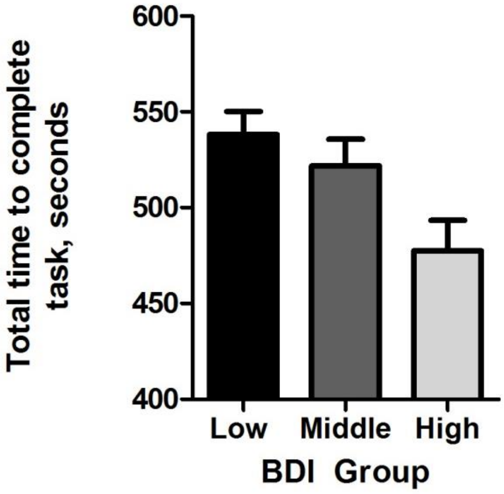


Figure 18: Completion time data for the EFT task, Experiment 5, split by BDI group.

Measures of response time and number of problems solved did not meet the assumption of normal distribution. Response time was skewed in a positive direction (W [88] = 0.90, $p < 0.001$) as the maximum possible time to complete the set of problems was 10 minutes, after which all participants were stopped. Total number of problems solved was skewed in a positive direction (W [88] = 0.810, $p < 0.001$) with participants predominantly solving between 16 and 18 of the 18 problems. Transforming this data did not correct the non-normal distribution. As non-normal distribution violates the assumptions of analysis of variance, non-parametric tests were used to analyse the relationship between BDI group, response time and problems solved.

There was a significant effect of BDI group on total time to complete the EFT (H [2] = 7.67, $p = 0.022$). Post hoc analysis (with Bonferroni correction applied to control for multiple comparisons, significance level is 0.016) indicated that the high BDI group completed the task significantly faster than the low BDI group (U (30, 30) = 272.50, $p < 0.01$). There was no significant difference between the middle BDI group and either the low (U (28, 30) = 371.50, $p = 0.445$) or high BDI group (U (28, 30) = 296.00, $p = 0.052$).

Faster completion time for the high BDI group is only meaningful if this group completed the same number of problems or more problems than the other groups. BDI groups did not differ significantly on total problems solved (H [2] = 4.03, $p = 0.133$).

A linear regression analysis, reported in Table 9, indicated that change in BDI score accounted for a significant proportion (11.5%) of variance in time taken to complete the EFT. As BDI score increased, time taken to complete the EFT decreased. This analysis met assumptions for regression analysis. Variance of residual terms was constant (homoscedasticity) and residual terms were uncorrelated (Durbin-Watson test score = 2.09). Distribution of residuals was normal.

Table 9: Regression analysis for the relationship between BDI and time taken to complete the EFT in Experiment 5.

	B	SE B	β
Step 1			
Constant	543.90	12.38	
Time taken to complete the EFT	-4.09	1.22	-0.34**

Note: $R^2 = 0.12$. $**p < 0.01$

4.1.3 DISCUSSION

Dysphoria, as identified by a higher BDI score, was associated with improved performance on the Embedded Figures Task. This suggests that dysphoria may be associated with enhanced ability to process details independently from the context in which they are presented. This extends previous research, demonstrating that, in terms of narrowing perceptual processing, dysphoria, as identified by high BDI scores, has a comparable influence to mood manipulations or the use of emotional stimuli.

While these results clearly indicate that performance on the EFT is associated with depressive state, determining what mechanisms drive this effect is complicated. Enhanced performance may be the result of improved processing of local details. The results may also indicate that dysphoria is associated with ability to process local details independently from the context in which they are presented. Equally however, enhanced performance may be interpreted as indicating that dysphoria is associated with allocating increased priority to goal relevant information, which here happened to be local details, at a cost to goal irrelevant information. Finally, enhanced performance may show that dysphoria is associated with greater capacity to bind simple features of an object, making objects easier to identify within the complex figure.

The Navon task can be used to test the contribution of some of these factors to performance in the EFT. Navon's (1977) hierarchical processing paradigm presents large letters composed of small letters. Participants are required to identify target letters presented either at a global (large letter) or local level (small letter). The Navon task can be considered from three perspectives, allowing three possible explanations for enhanced performance on the EFT to be tested. First, the Navon task can be used to test whether dysphoria is directly associated with a tendency to focus on details rather than global context. Secondly, the task can test whether dysphoria is associated with enhanced ability to ignore peripheral information while identifying specific details. Finally the Navon task can be used to test whether dysphoria is associated with increased ability to prioritise goal relevant information at the cost of goal irrelevant information.

To compare ability to focus on details rather than the context, the Navon task can be used to test ability to find targets presented at a global or local level. If enhanced performance on the EFT was driven by a tendency to focus on the details, dysphoria should be associated with faster identification of targets presented at a local level.

Comparing performance on congruent and incongruent trials of the Navon task should test whether dysphoria is associated with enhanced ability to ignore peripheral information while identifying specific details. The Navon task contains incongruent trials, where the information presented at local and global levels is different. This allows a test of the influence that global information has upon identification of targets presented at the local level. If individuals with high BDI scores showed enhanced performance on the EFT because they were able to process details while ignoring the context in which the details were presented, dysphoria should be associated with a lack of congruency effect when identifying targets at the local level. Specifically, the ability of individuals with high BDI scores to respond to targets presented at the local level should not be affected by the information presented at the global level.

Finally, throughout the Navon task participants attempt to identify targets at one hierarchical level (local or global) while ignoring information presented at the other hierarchical level. As such, there is a demand to attend and respond to goal relevant information, while ignoring goal irrelevant information. If enhanced performance on the EFT is to be accounted for in terms of ability to prioritise goal relevant information, individuals with high BDI scores should perform better on the Navon task than individuals with low BDI scores, regardless of whether they are identifying local or global information. Ability to process goal relevant information while ignoring goal irrelevant information should be associated with no increase in response time on incongruent (where goal relevant and irrelevant information differ) relative to congruent trials.

Experiment 6 tested whether dysphoria is associated with a simple shift in focus towards local level information. Experiments 7 and 8 assessed whether dysphoria is associated with ability to respond to local details while ignoring the context or ability to prioritise goal relevant information.

4.2 EXPERIMENT 6

While the original Navon task, described in previous chapters, compared performance on congruent and incongruent trials, variations of the Navon task have been used which, on each trial simply require participants to identify whether a target letter is presented. The target letter may, on different trials, be presented at the local or global level. Response time is measured, providing an assessment of the relative ease of processing global as opposed to local information. If dysphoria facilitates processing of local details, dysphoria should be associated with faster identification of targets presented at the local level.

4.2.1 METHODS

4.2.1.1 PARTICIPANTS

Fifty four university students participated for course credit or were paid £5.00 for their participation. Participants were categorised into two groups on the basis of a median split of BDI score, 6.20 (6.72). Demographics for participants split into two BDI groups are shown in Table 10. Separately from this, participants were also categorised into two neuroticism groups on the basis of a median split of neuroticism score, as measured using the NEO-PI-R, 81.74, (27.91)[1], shown in Table 10.

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[1] In previous studies neuroticism has been measured using binary scoring, giving a much lower average score. Here neuroticism has been measured on a likert scale.

Table 10: Demographics for participants completing the Navon Task, Experiment 6, split by BDI Group.

	BDI Group	
	Low (non-dysphoric)	High (dysphoric)
N	30	24
BDI Score	1.57 (1.57)	12.00 (6.16)
Neuroticism Score	71.10 (17.19)	95.04 (20.04)
Age, years	22.13 (4.99)	21.00 (4.04)
Gender (males)	5	5

Table 11: Demographics for participants completing the Navon Task, Experiment 6, split by Neuroticism Group.

	Neuroticism Group	
	Low	High
N	26	28
BDI Score	2.88 (3.91)	9.29 (7.35)
Neuroticism Score	71.13 (16.63)	97.18 (19.55)
Age, years	21.85 (4.76)	21.43 (4.50)
Gender (males)	7	3

BDI and neuroticism score correlated significantly ($r = 0.62$, $p < 0.001$). Average age was 21.63 years and did not correlate significantly with either BDI score ($r = -0.13$, $p = 0.354$) or neuroticism score ($r = -0.19$, $p = 0.174$). Gender was not associated with significant differences in BDI score ($U (10, 44) = 214.5$, $p = 0.902$) or neuroticism score ($U (10, 44) = 150.0$, $p = 0.119$).

4.2.1.2 APPARATUS

All participants completed the BDI (Beck, 1972) and the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995). As described in previous experiments, only the neuroticism subsection of the NEO-PI-R was administered. In contrast to previous experiments, the NEO-PI-R here was completed using a 5 point likert scale. The questionnaire consisted of 48 items, to which participants responded on a five point likert scale, ranging from “strongly disagree” to “strongly agree”. As discussed in Experiment 1, correlation between participants’ neuroticism scores as measured using a binary item format on the NEO-PI-R and a 5 point likert scale was high (r = 0.88).

Navon Task

This version of the Navon task, presented on a computer (programmed in Visual Basic), used 16 stimuli consisting of a large letter composed of smaller letters. In four stimuli the target letter (E or H) was presented at the global level (Et, Ev, Hi, Hx). In four stimuli the target letter was presented at the local level (Lh, Xh, Ve, Te). Eight stimuli, included as catch trials, did not include a target letter (Xv, Xt, Vx, Vl, Tx, Tl, Lv, Lt). All stimuli consisted of black letters presented on a white background. Stimuli were presented in a rectangle with the large letters spanning approximately 4.75 x 8.00 cm and the small letters spanning approximately 0.90 x 1.10 cm.

4.2.1.3 PROCEDURE

At the test session participants initially completed the questionnaires (BDI then NEO-PI-R). The Navon task consisted of 15 blocks of 16 trials (240 trials in total). Participants were required to press a response key as soon as they saw either of the target letters, regardless of the level at which it was presented. The response key was the letter G, however, on the keyboard used, the letter was covered with a star to make the response key easy to identify. Participants used the same response key for both target letters and were instructed to make no response on trials where the target letters were not presented.

Each trial started with a fixation point, presented in the centre of the screen for a 500ms. This was replaced by the stimulus, presented for 150ms. Following the stimulus a mask, consisting of an array of small letters, was presented for 2000ms or until a response was made. Upon making a response participants were given feedback on the accuracy of their response and presented with an on-screen button to click for the next trial. If their response was accurate, the word “correct” appeared in black letters on the centre of the screen. If their response was inaccurate, the word “incorrect” appeared in black letters on the centre of the screen.

After the first 10 trials, participants were asked if they understood how the task worked. If at this point they did not understand what was required, the instructions were re-read. Instructions were re-read or clarified for approximately 30% of participants. At 120 trials participants were alerted to the fact that they were half way through the task. It was recommended that participants take a break at this point. The length of this break was not constrained; on average participants paused for between 30 seconds and two minutes.

4.2.2 RESULTS

Reaction time and response accuracy were recorded and compared across global and local trials. Through analysis, the impact upon performance on this task of BDI and neuroticism score, and the interaction between the two was assessed. Analysis of reaction time data included reaction time on correct trials only. Analysis of the distribution of response times indicated one outlier. This participants' reaction time to global trials was more than 5 standard deviations above the mean. This participant was removed from analysis. Reaction time to local and global targets for all other participants was within 2 standard deviations above or below the mean and reaction times to local and global targets were normally distributed: low neuroticism group, local targets (W [25] = 0.959, p = 0.390) and global targets (W [25] = 0.947, p = 0.217); high neuroticism group, local targets (W [28] = 0.955, p = 0.259) and global targets (W [28] = 0.985, p = 0.946).

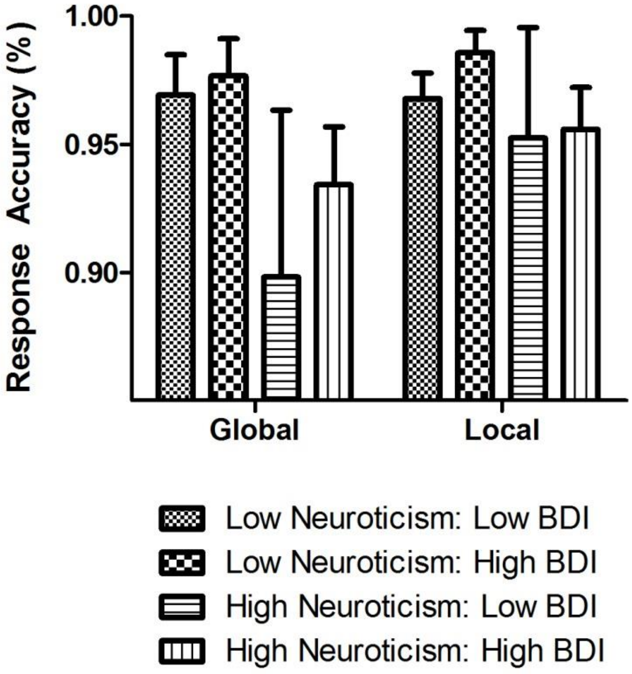

Figure 19: Response accuracy for the Navon task, Experiment 6.

Response accuracy, shown in Figure 19, was comparable across all conditions. Response accuracy scores were non-normally distributed. Response accuracy was positively skewed in all conditions, with participants tending towards 100% accuracy. Transforming response accuracy scores did not correct the distribution. Therefore non-parametric tests were used to compare the effect of target level (local vs. global), BDI (low vs. high) and neuroticism score (low vs. high) on response accuracy. Response accuracy did not differ significantly between the local and global conditions (χ_F^2 [1] < 1, p = 0.527). Response accuracy did not differ significantly between BDI groups in either the global (U (30, 23) = 262, p = 0.137) or local (U (30, 23) = 318, p = 0.659) condition. Response accuracy did not differ significantly between neuroticism groups in either the global (U (26, 27) = 254.50, p = 0.076) or local (U (26, 27) = 312, p = 0.471) condition.

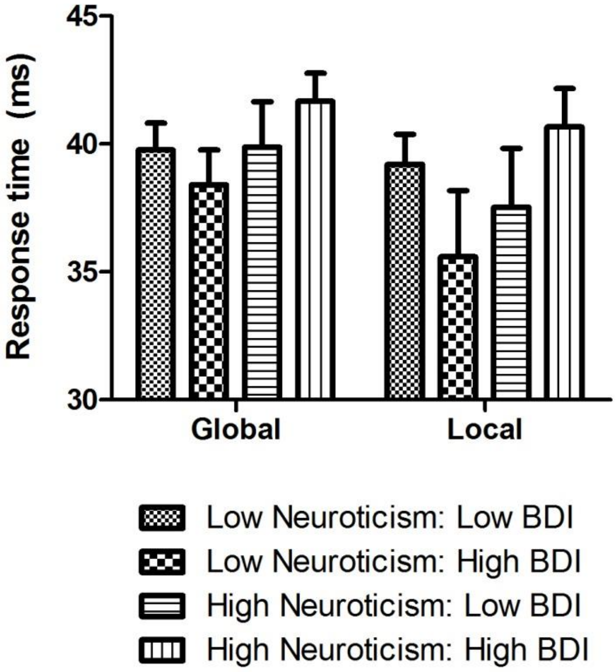

Figure 20: Response time for the Navon task, Experiment 6.

Response time data shown in Figure 20, suggests no substantive group differences. A repeated measures ANOVA was used to compare the effect of the same factors on response time. There was a significant main effect of target level (F [1, 49] = 4.74, p = 0.034), with participants responding faster to local targets than global targets. There was no main effect of BDI group (F [1, 49] < 1, p = 0.994) or neuroticism group (F [1, 49] = 1.16, p = 0.287). There was no significant interaction between target level and BDI group (F [1, 49] < 1, p = 0.085) or neuroticism group (F [1, 49] < 1, p = 0.991) and no significant three way interaction (F [1, 49] = 1.35, p = 0.251).

To assess whether the absence of effect was due to the median split adopted, the full range of BDI and neuroticism scores were considered and the relationship between these scores and response time was calculated. The additional time taken to identify a target presented at a local level was calculated by subtracting the response time to targets presented at a global level from the response time to targets presented at a local level. Linear regression analysis indicated that neither BDI score (f [1, 51] < 1, p = 0.374) or neuroticism score (f [1, 51] < 1, p = 0.958) accounted for a significant proportion of the variance in response time difference. Together these factors accounted for less than 1% of the variance in response time difference. This was not significant (f [2, 50] < 1, p = 0.559).

4.2.3 DISCUSSION

The aim of this study was to test whether dysphoria or neuroticism were associated with a tendency towards processing specific details. The study provided no support for the hypothesis that dysphoria, as measured by the BDI, or neuroticism, as measured by the NEO-PI-R, is associated with improved ability to identify targets presented at a local level. Individuals did not differ in the ease with which they identified targets presented at a local or global level. As such the association between dysphoria and performance on the EFT is unlikely to be accounted for in terms of difference in ability to identify specific details.

4.3 EXPERIMENT 7

Experiment 6 showed no relationship between BDI score and ability to detect target letters presented at a local or global level. This suggests that the relationship between BDI score and performance on the EFT is more complex than simply a bias in attention towards local level information. The original Navon local-global paradigm (Navon, 1977) tests the effect of the congruency of the information presented at different levels and the effect of goal relevance. It is possible that differences in the ability to process specific details while ignoring context information or differences in the ability to prioritise goal relevant information underlie individual difference in EFT performance.

Through the Navon task, local information is embedded within global information, as such global information may act as the context within which local information is presented. If enhanced performance on the EFT was facilitated by ability to process detailed information independent from the context in which it was presented, dysphoria should be associated with ability to respond to targets presented at the local level, without being influenced by global information. Performance on local congruent and incongruent trials can be compared to assess the impact that global information has upon processing local information. On a congruent trial, information presented at the local and global level is the same. On an incongruent trial the information presented at the global level differs from the information presented at the local level. If global information influences processing of local information, contrasting global information should delay responding to local information. As such responding to targets presented at the local level should be faster on congruent than incongruent trials. Individuals with high BDI scores may be expected to respond at the same speed to congruent and incongruent local stimuli. In other words, congruency should not influence responding to local information for participants with high BDI scores.

Dysphoria may also have been associated with enhanced performance on the EFT because of ability to prioritise processing of goal relevant information. All incongruent trials in the Navon task required participants to attend to goal relevant information while ignoring goal irrelevant information. If performance on the EFT was enhanced due to prioritised processing of goal relevant information, dysphoria should be associated with unimpaired responding on incongruent conditions, regardless of the level at which information was presented. In other words, participants with high BDI scores should show no effect of congruency on local or global trials.

Through this experiment, the BDI alone was administered. Experiment 8 replicated this experiment, measuring neuroticism as well as BDI.

4.3.1 METHOD

4.3.1.1 PARTICIPANTS

125 university students participated for course credit or were paid £5 for their participation. As described in Experiment 6, participants were categorised into two groups on the basis of a mean split of BDI score, 7.65 (8.05). Average participant age was 20.83 (3.51) years. Older participants had significantly higher BDI score ($r = 0.21$, $p = 0.02$). Average digit span was 7.14 (0.79) digits. High BDI score was associated with shorter digit span ($r = - 0.24$, $p < 0.01$). The dysphoric group (high BDI score) were

significantly older than the non-dysphoric group (t [123] = -2.81, p < 0.01) and had significantly shorter digit span (t [123] = 2.45, p = 0.016). There was no significant difference in BDI score between male and female participants (U = 1588, p = 0.951). Figure 12shows participant demographics.

Table 12: Demographics for participants completing the Navon task, Experiment 7, split by BDI.

	BDI Group	
	Non-dysphoric (low)	Dysphoric (high)
N	62	63
BDI score	2.50 (1.94)	13.54 (5.60)
Age, years	20.03 (1.98)	21.80 (4.51)
Digit span, digits recalled	7.35 (0.87)	6.96 (0.82)
Gender (Males)	21	20

4.3.1.2 APPARATUS AND PROCEDURE

Digit span and BDI were measured. As described in Experiment 5, participants completed the BDI between 48 hours and two weeks prior to the test session. Average BDI score was calculated from the two test time points. The Navon task was conducted as described in Experiment 3, with one change in procedure. Through the Navon task four separate stimuli are presented on a computer (two congruent stimuli and two incongruent stimuli). All stimuli consist of large letters (S or H) composed of small letters (S or H). Participants are asked in separate trial blocks, either to identify the large letter or the small letter. In Experiment 3, participants responded by pressing keys on the keyboard. In this experiment participants responded using the mouse to click on one of two buttons on the screen; **S** was presented just left of the centre of the screen while **H** was presented just right of the centre of the screen. Participants completed tasks in the following order; digit span, BDI and Navon task.

4.3.2 RESULTS

As described in Experiment 3, reaction time and response accuracy were recorded for the Navon task. Outlying response times for each participant were removed as described in Experiment 3. Reaction time for all four conditions was significantly skewed; global congruent ($W [125] = 0.948$, $p < 0.001$), global incongruent ($W [125] = 0.953$, $p < 0.001$), local congruent ($W [125] = 0.874$, $p < 0.001$) and local incongruent ($W [125] = 0.947$, $p < 0.001$). All response times were transformed (logarithmic transformation). Following transformation, reaction time remained non-normally distributed for the high BDI group in the local congruent condition ($W [63] = 0.941$, $p < 0.01$) and the low BDI group in the global congruent condition ($W [62] = 0.959$, $p = 0.039$). Reaction time for one participant in the high BDI group for the local congruent condition was more than 3.5 standard deviations above the mean. After removing this participant from the analysis, the reaction times in the local congruent condition met assumptions of normality ($W [62] = 0.973$, $p = 0.194$). Reaction times for all other participants, in all conditions, were within 3 standard deviations of the mean. Similar steps could not be taken to correct for the non-normal distribution of reaction times in the global congruent condition for the low BDI group, however, the deviation from normality is comparable small. As group sizes were equal, the F-statistic should be robust to violations of normality for two-tailed tests (Donaldson, 1968; Glass, Peckham, & Sanders, 1972).

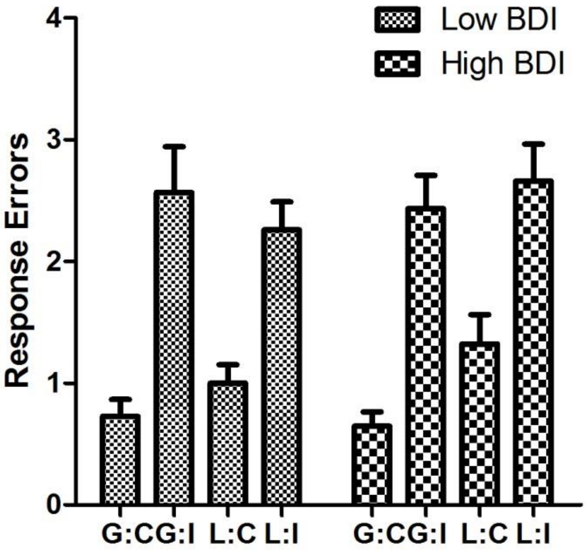

Figure 21: Response errors for participants completing the Navon Task, Experiment 7. G – Global; L – Local; C – Congruent; I – Incongruent.

Figure 21 shows response errors, suggesting that while participants made fewer errors on congruent than incongruent trial, neither BDI score nor the hierarchical level at which a stimulus was presented influenced response accuracy. Response error data were not normally distributed in any condition, with the majority of participants making no errors. Transforming this data had minimal effect on the normality of distribution. As such, non-parametric tests were used to compare the accuracy of responding between conditions. Participants' response accuracy differed significantly between the four conditions (χ^2_F [3] = 104.98, p < 0.001). Wilcoxon tests were used to follow up this finding. Participants made significantly more errors responding on incongruent than congruent trials (T = 411, p < 0.001). Response accuracy when responding to local and global targets did not differ significantly (T = 2185, p = 0.103).

Participant groups (low vs. high BDI) did not differ significantly in the number of errors made on any of the four conditions; global congruent (U (62, 62) = 1906, p = 0.928), global incongruent (U (62, 62) = 1799, p = 0.532), local congruent (U (62, 62) = 1863.5, p = 0.756) or local incongruent (U (62, 62) = 1813.5, p = 0.582).

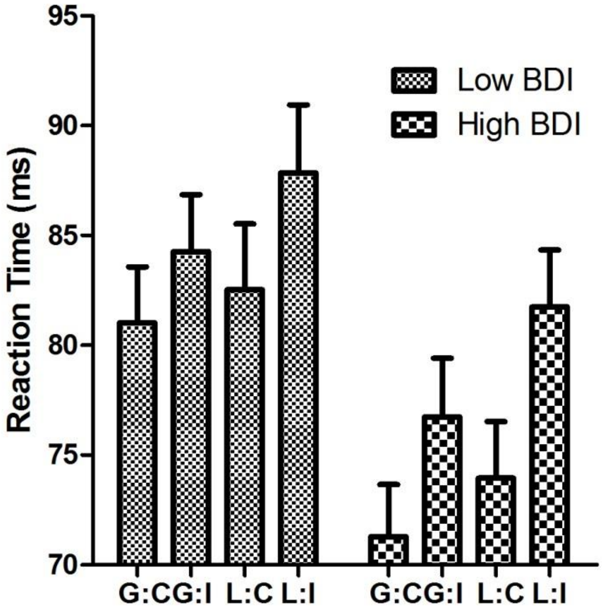

Figure 22: Untransformed response time for participants completing the Navon task, Experiment 7. G – Global; L – Local; C – Congruent; I – Incongruent.

Figure 22, showing reaction time,[2] suggests that while participants with high BDI scores were faster to respond to all trial types, there were no systematic differences between the two groups. A 2x2x2 way ANOVA was conducted on reaction time with the factors of; target level (local vs. global), congruency (congruent vs. incongruent) and BDI (low vs. high). The high BDI group (dysphoric group) responded significantly

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[2] The graph shows untransformed reaction times to illustrate the actual reaction times observed. Analysis has been conducted on a logarithmic transformation of reaction times.

faster than the low BDI group (F [1, 122] = 5.84, p = 0.017). All participants were faster to respond to targets presented at the global level than local level (F [1, 122] = 4.68, p = 0.032) and were faster responding on congruent than incongruent trials (F [1, 122] = 52.56, p < 0.001). There was no significant interaction between BDI group and target level (F [1, 122] < 1, p = 0.406) or trial congruency (F [1, 122] < 1, p = 0.069). There was no significant three way interaction (F [1, 122] < 1, p = 0.772).

The relationship between performance on the Navon task and BDI score was considered in a continuous fashion to allow analysis of interactions between BDI score, digit span and age. Ability to engage in goal directed responding was identified as the difference in response time between congruent and incongruent trials. The average response time to global and local congruent trials was subtracted from the average response time to global and local incongruent trials. This congruency difference score gives a measure of the additional time taken to respond to an incongruent trial over and above the time taken to respond to a congruent trial. BDI score alone accounted for less than 1% of the variance in goal directed responding; this was not significant (F [1, 116] = 1.52, p = 0.221). Inclusion of other factors in the model did not increase the variance in goal directed responding accounted for and the change in F statistic was not significant for any of these factors; digit span (F_{change} [1, 115] = 2.99, p = 0.086), age (F_{change} [1, 115] = 1.762, p = 0.187), gender (F_{change} [1, 115] < 1, p = 0.944).

The influence of global information upon identification of local information was tested by looking at ability to identify local targets on incongruent trials relative to congruent trials. Response time on local congruent trials was subtracted from response time on local incongruent trials to give a measure of the extent to which incongruent global information slows responding to local information. BDI score alone accounted for less than 1% of the variance in the ability to identify local information on incongruent trials; this was not significant (F [1, 116] = 1.82, p = 0.180). Inclusion of other factors in the model did not significantly increase the variance in accounted for and the change in F statistic was not significant for any of these factors; digit span (F_{change} [1, 115] = 3.34, p = 0.070), age (F_{change} [1, 115] < 1, p = 0.657), gender (F_{change} [1, 115] < 1, p = 0.663).

4.3.3 DISCUSSION

This experiment tested whether the association between high scores on the BDI and good performance on the EFT could be explained by ability to process local level information independent from the context in which it was presented or ability to prioritise goal relevant information. Dysphoria was not associated with improved ability to prioritise goal relevant information, or increased ability to respond to local information without being influenced by the surrounding context. All participants responded faster to global targets and congruent trials.

4.4 EXPERIMENT 8

Experiment 7 did not find dysphoria to be associated with specific changes in performance on the Navon task. Thus Experiment 8 assessed whether neuroticism score accounts for variance in performance on the Navon task. Further, in Experiment 7, participants responded using the mouse to click a button on the screen. Response times in Experiment 6, where participants were using response keys on the keyboard, were around 40 ms. In Experiment 7, where participants were responding by using the mouse to press a button on the screen, response times were twice this, with participants taking, on average, 80 ms to respond. This increase in response latency may have obscured group differences. Therefore, in this experiment participants were asked to respond using response keys on the keyboard.

4.4.1 METHOD

4.4.1.1 PARTICIPANTS

105 university students participated for course credit or were paid £5 for their participation. As described in Experiment 6, participants were categorised into one of two groups on the basis of a mean split of BDI score, 6.99 (6.99) and separately categorised into one of two neuroticism groups on the basis of a median split of neuroticism score, 18.85 (8.72). Table 13 and

Table 14 show demographics for participants completing this experiment.

Table 13: Demographics for participants completing Experiment 8, split by BDI score.

	BDI Group	
	Non-dysphoric (low)	Dysphoric (high)
N	55	50
Average BDI	2.33 (2.13)	12.31 (6.81)
Neuroticism score	13.69 (6.02)	24.52 (7.65)
Age, years	20.55 (2.71)	20.06 (2.09)
Digit span, digits recalled	7.49 (0.71)	7.44 (0.64)
Gender (male)	11	11

Table 14: Demographics for participants completing Experiment 8, split by neuroticism score.

	Neuroticism score	
	Low	High
N	51	54
Average BDI	3.43 (3.67)	11.06 (7.68)
Neuroticism score	11.65 (3.73)	25.65 (6.24)
Age, years	25.36 (2.55)	20.28 (2.35)
Digit span, digits recalled	7.55 (0.68)	7.39 (0.67)
Gender (male)	14	8

BDI and neuroticism score were correlated significantly (r = 0.64, p < 0.001). Average age was 20.32 (2.44) years. Age did not correlate significantly with either BDI score (r = -0.15, p = 0.204) or neuroticism score (r = 0.01, p = 0.991). Average digit span was 7.46 (0.67) digits. Digit span did not correlate significantly with either BDI score (r = -0.08, p = 0.505) or neuroticism score (r = 0.09, p = 0.420). Gender was not associated with significant differences in BDI score (U (22, 83) = 459, p = 0.644) or neuroticism score (U (22, 83) = 696, p = 0.134).

4.4.1.2 APPARATUS AND PROCEDURE

All participants completed the digit span assessment (Lezak, 1995) and the BDI (Beck, 1972) as described in Experiment 7. Participants completed the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995), as described in Experiment 1 and the Navon Task. The Navon task was completed as described in Experiment 7, with the exception of how participants responded. Participants responded with either the **S** or the **H** key on the keyboard, using their left index finger for **S** and their right index finger for **H**.

4.4.2 RESULTS

As described in Experiments 3 and 7, reaction times and response accuracy were recorded. Outlying response times for each participant were removed as described in Experiment 3. Reaction time for correct trials only was analysed. Reaction time for all four conditions was significantly skewed; global congruent (W [105] = 0.731, $p < 0.001$), global incongruent (W [105] = 0.814, $p < 0.001$), local congruent (W [105] = 0.834, $p < 0.001$) and local incongruent (W [105] = 0.752, $p < 0.001$). As described in Experiment 7, all data were transformed with a logarithmic transformation. Following transformation, reaction time remained non-normally distributed for all conditions for the high neuroticism group. Mean and standard deviation were calculated for each condition and participants with response times of more than 3 standard deviations above the mean were excluded from analysis; this excluded 4 participants, two from the high neuroticism group and two from the low neuroticism group. After removing these participants the assumption of normal distribution was met for all conditions.

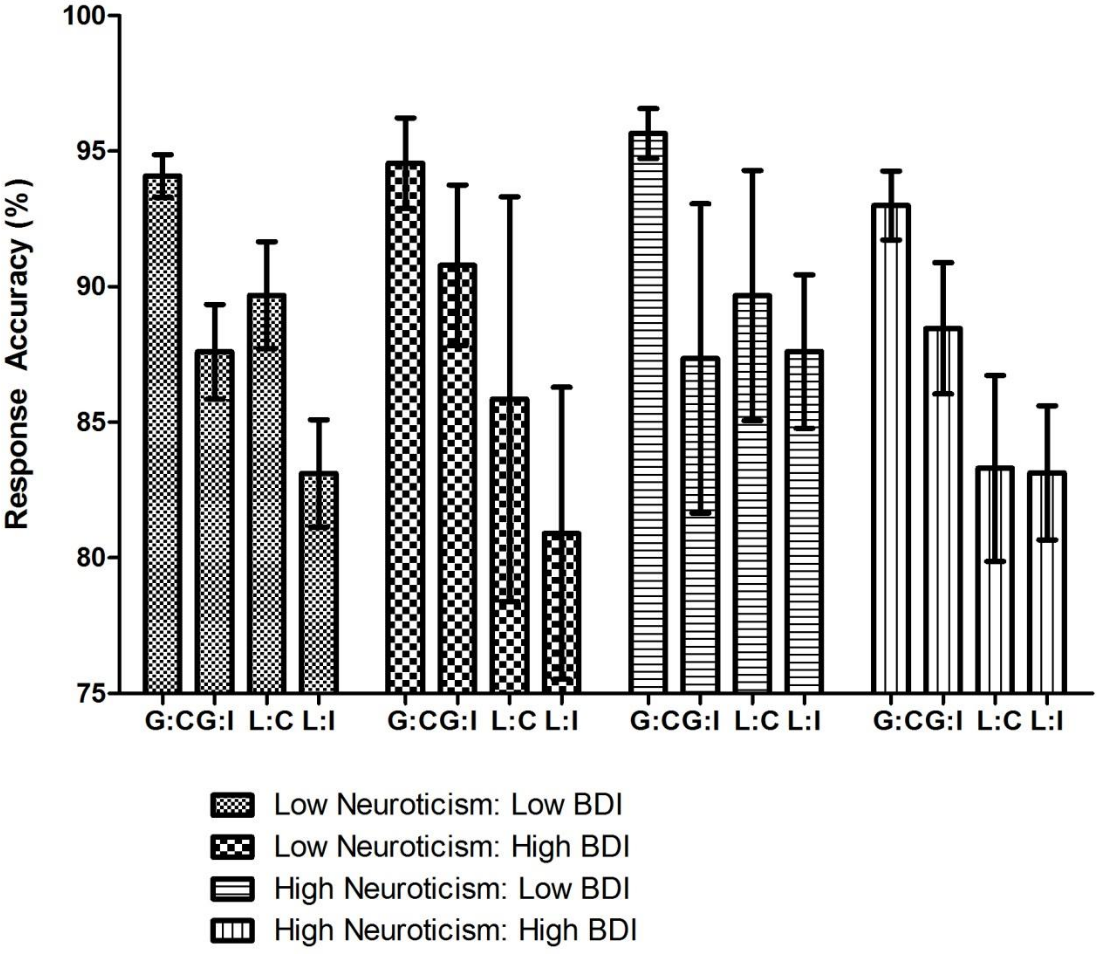

Figure 23: Response Accuracy for participants in Navon task, Experiment 8, G – Global; L – Local; C – Congruent; I – Incongruent.

Figure 23, showing response accuracy, suggests that while participants were more accurate responding on congruent than incongruent trials, differences in response accuracy between groups were minimal. Response accuracy data were not normally distributed in any of the conditions. For all conditions, response accuracy was positively skewed, with participants tending towards 100% accuracy. Transforming this data had minimal effect on the normality of distribution. As such, non-parametric tests were used to compare the accuracy of responding between conditions. Participants' response accuracy differed significantly between the four conditions (χ_F^2 [3] = 44.73, p < 0.001). Wilcoxon tests were used to follow up this finding. Participants were significantly more accurate responding on congruent than incongruent trials (T = 1200.50, p < 0.001) and significantly more accurate responding to global than local targets (T = 1211, p < 0.001). Importantly, however, neuroticism groups (low vs. high) did not differ significantly in response accuracy on any of the four conditions; global congruent (U (49, 52) = 1265.50, p = 0.953), global incongruent (U (49, 52) = 1100.50, p = 0.233), local congruent (U (49, 52) = 1177, p = 0.500) or local incongruent (U (49, 52) = 1155.5, p = 0.419). Similarly, BDI groups (low vs. high BDI) did not differ significantly in response accuracy on any of the four conditions; global congruent (U = (53, 48) 1261.50, p = 0.931), global incongruent (U (53, 48) = 1112, p = 0.265), local congruent (U (53, 48) = 1159.50, p = 0.426) or local incongruent (U (53, 48) = 1269, p = 0.973).

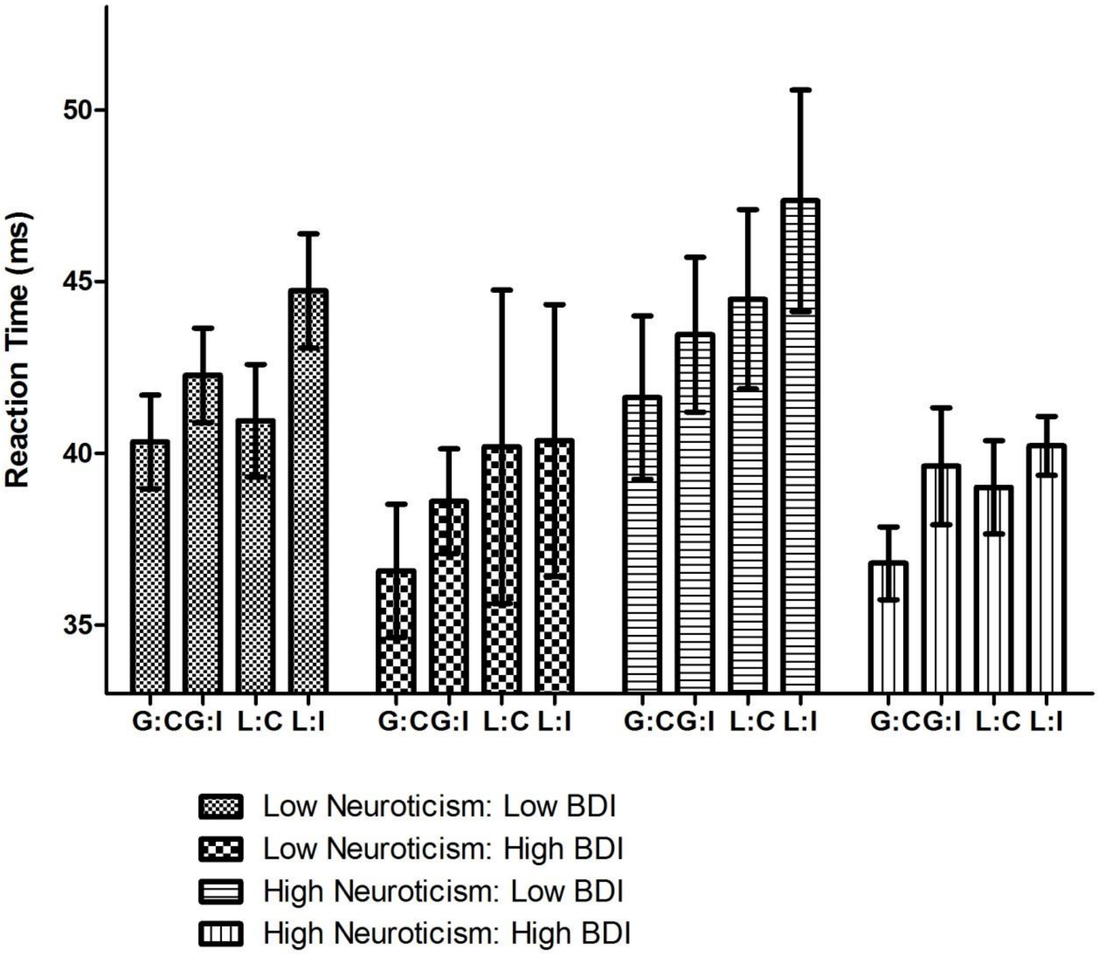

Figure 24: Response time for participants in Navon task, Experiment 8, G – Global; L – Local; C – Congruent; I – Incongruent.

Figure 24 shows response times split by neuroticism and BDI score[3]. There do not appear to be any systematic differences between groups. A 2x2x2x2 way ANOVA was conducted on response time with the factors of; target level (local vs. global), congruency (congruent vs. incongruent) BDI group (low vs. high) and neuroticism group (low vs. high). Participants in the high BDI group responded significantly faster

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[3] While analysis is conducted on transformed data, the graph shows untransformed data.

than participants in the low BDI group (F [1, 97] = 5.47, p = 0.021). There was no significant main effect of neuroticism group (F [1, 97] <1, p = 0.513) and no significant interaction between BDI and neuroticism group (F [1, 97] <1, p = 0.576).

All participants responded significantly faster to targets presented at the global level than the local level (F [1, 97] = 6.14, p = 0.015). There was no significant interaction between target level and BDI group (F [1, 97] <1, p = 0.849) or neuroticism group (F [1, 97] <1, p = 0.563) and no significant three way interaction (F [1, 97] <1, p = 0.627).

All participants responded significantly faster on congruent trials than incongruent trials (F [1, 97] = 9.98, p < 0.01). There was no significant interaction between congruency and BDI group (F [1, 97] <1, p = 0.660) or neuroticism group (F [1, 97] < 1, p = 0.938) and no significant three way interaction (F [1, 97] <1, p = 0.638).

There was no significant interaction between target level and congruency (F [1, 97] <1, p = 0.960) and no significant three way interaction between these two factors and BDI group (F [1, 97] = 1.67, p = 0.200) or neuroticism group (F [1, 97] <1, p = 0.932).

As described in Experiment 7, performance on the Navon task was considered in a continuous fashion to allow further analysis of how factors interacted to influence performance. Ability to prioritise goal relevant information was explored with analysis of congruency difference score, calculated as described in Experiment 7. Neuroticism alone accounted for less than 1% of the variance in goal directed responding, this was not significant (F [1, 99] <1, p = 0.880). BDI score alone accounted for less than 1% of variance and this was not significant (F [1, 99] <1, p = 0.400). Combined these factors still accounted for less than 1% of the variance (F [2, 99] <1, p = 0.594). Inclusion of other factors in the model did not increase the variance in goal directed responding accounted for and the change in F statistic was not significant for any of these factors; digit span (F_{change} [1, 63] = 3.01, p = 0.088), age (F_{change} [1, 66] = 1.31, p = 0.257), gender (F_{change} [1, 67] < 1, p = 0.408).

Ability to respond to local level information independent from the context in which it is presented was explored with analysis of local congruency score, as described in Experiment 7. Neuroticism accounted for less than 1% of the variance in the ability to identify local information on incongruent trials; this was not significant (F [1, 99] < 1, p = 0.368). BDI score alone accounted for less than 1% of the variance; this was not significant (F [1, 99] = 1.674, p = 0.199). Combined these factors accounted for less than 1% of the variance (F [2, 98] = < 1, p = 0.352). Inclusion of other factors in the model did not significantly increase the variance in accounted for and the change in F statistic was not significant for any of these factors; digit span (F_{change} [1, 72] < 1, p = 0.368), age (F_{change} [1, 91] < 1, p = 0.593), gender (F_{change} [1, 95] < 1, p = 0.202).

4.4.3 DISCUSSION

While dysphoria was associated with enhanced performance on the EFT, neither dysphoria nor neuroticism appears to be associated with difference in performance on the Navon task. Neither dysphoria nor neuroticism were associated with improved ability to identify targets presented at the local level, identify details while ignoring global, context, information or prioritise goal relevant information.

If the Navon and the EFT are both sensitive to ability to process local relative to global level information, why should an effect of dysphoria be observed in completion of the

EFT but not the Navon task? Unlike the Navon task, the EFT might require specific details to be identified and then bound together. The Navon task does not require participants to group individual letters. Therefore the difference in findings may be accounted for in terms of requirement to bind information or form conjunctions of co-occurring information. If individuals were good at this aspect of the EFT specifically, they should not show improved performance on the Navon task.

The discrepancy in findings may also arise due to differences in the time frame within which participants respond. While response time is a fundamental marker for successful performance in the EFT and the Navon, the time frame for responding differs. The EFT assesses what can be achieved in a period of time of minutes. The Navon task measures reaction time, where differences in performance may occur in the magnitude of milliseconds. It is plausible that this assessment would be insensitive to difference between individuals differing in BDI score or neuroticism.

4.5 EXPERIMENT 9: CONJUNCTION FORMATION

The EFT requires participants to group specific features together (the simple figure) and hold these in mind while searching for the simple figure in a complex diagram. Finding the simple figure depends on identifying co-occurring features rather than looking for separate features. For example, to find a diamond shape within the complex figure, participants need to identify the co-occurrence of a group of angles rather than looking for each angle separately. Figure 25 illustrates the difference between searching for co-occurring features and specific individual features. While there are only two possible options for isolating the correct combination of co-occurring features, there are at least 28 different specific corners that could be relevant to the identification of the simple shape. Enhanced performance on the EFT may be facilitated, in part, by ability to bind features together and search for the co-occurrence of features. If so, dysphoria should be associated with improved ability to identify the conjunctions of features.

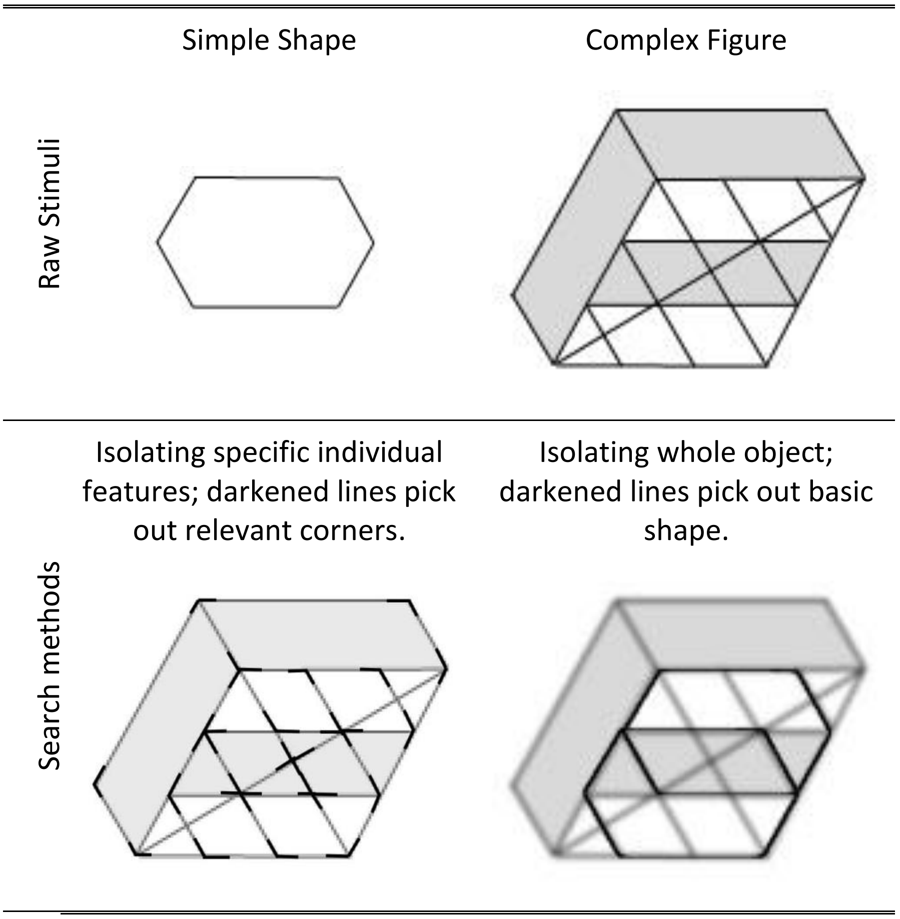

Figure 25: Sample EFT simple shape and complex figure, described in Experiment 5, detailing two possible search strategies; searching for specific individual features and searching for the whole object.

Ability to find conjunctions can be tested using a visual search task. Treisman's (1980) feature search task requires participants to search for a simple feature or conjunction of features on different trials. To the extent that identifying conjunctions is harder than identifying features, participants should be slower to identify a target on a conjunction trial than a feature trial.

The Triesman feature search task presents two different trial types (Treisman & Gelade, 1980). On a feature trial, participants are required to locate a target (i.e., a blue T) among distractors that share only one feature in common (i.e., brown T's). On a conjunction trial, participants are required to locate a target (i.e., a green T) that shares both features in common with the presented distractors (i.e., brown T's and green **X**'s). On these trials, the target can only be identified by the conjunction of the two features.

Feature integration theory assumes that in perception features come first (Treisman & Gelade, 1980). Features are registered early, automatically and in parallel. There should be no attentional limits to detecting features. Increasing the number of distractors presented alongside the target (the array size) should not influence ability to identify the target. Triesman and Gelade (1980) argue that the objects which features compose are identified separately and at a later stage. The recognition of objects is assumed to require attention and it is focal attention which provides the "glue" to integrate separate features into unitary objects. As attention is necessary for the perception of conjunctions of features, detection of conjunctions should require a serial scan of the features presented. The length of time that it takes to complete a serial search should increase as the number of distracters, and thus the number of conjunctions needing to be scanned, increases.

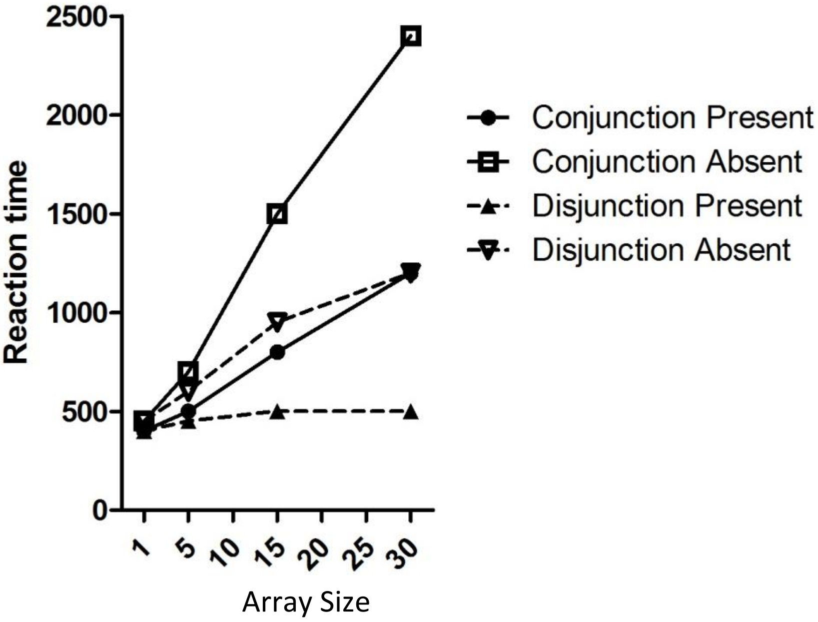

Figure 26: Original Feature Search Effect, redrawn from Treisman and Gelade (1980).

Figure 26 illustrates the standard findings observed using this form of task. While response time on a feature trial does not increase as the number of distracters presented increases, response time for conjunction trials slows incrementally as the number of distracters increases.

If neuroticism or dysphoria are associated with an advantage identifying conjunctions, high BDI scores or high neuroticism should be associated with relatively rapid responses on conjunction condition trials and less difference in the response time between conjunction and feature trials.

4.5.1 METHOD

4.5.1.1 PARTICIPANTS

Forty nine university students participated for course credit or were paid £5 for their participation. As described in Experiment 8, participants were divided into two groups following a median split of neuroticism score, 19.88 (8.91) and separately divided into two groups following a median split of BDI score, 7.04 (7.35). Table 15 and Table 16 show demographics for participants completing this experiment, split by neuroticism score and BDI score respectively.

Table 15: Demographics for participants completing the Feature Search Task, Experiment 9, split by neuroticism score.

	Neuroticism group	
	Low	High
N	25	24
Neuroticism score	12.60 (4.24)	27.46 (5.43)
BDI score	2.92 (3.41)	11.33 (7.93)
Age, years	20.36 (3.12)	27.46 (5.43)
Digit span, digits recalled	7.50 (0.66)	7.25 (0.61)
Gender (males)	8	5

Table 16: Demographics for participants completing the Feature Search Task, Experiment 9, split by BDI score.

	BDI group	
	Non-dysphoric (low)	Dysphoric (high)
N	21	28
Neuroticism score	27.14 (6.61)	14.43 (6.08)
BDI score	13.67 (6.70)	2.07 (1.74)
Age, years	22.14 (4.65)	20.46 (2.90)
Digit span, digits recalled	7.24 (0.70)	7.48 (0.58)
Gender (males)	5	8

BDI and neuroticism score were correlated significantly (r = 0.73, p < 0.001). Average age was 21.18 (3.80) years. Age did not correlate significantly with either BDI score (r = 0.13, p = 0.372) or neuroticism score (r = 0.28, p = 0.052). Average digit span was 7.38 (0.64) digits. Digit span did not correlate significantly with either BDI score (r = -0.08, p = 0.61) or neuroticism score (r = -0.22, p = 0.14). Gender was not associated with a significant difference in BDI score (U (13, 36) = 201.50, p = 0.457) or neuroticism score (U (13, 36) = 209, p = 0.571).

4.5.1.2 APPARATUS

All participants completed the digit span task (Lezak, 1995), the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995) and the BDI (Beck, 1972) as described in Experiment 8.

Treisman Feature Search Task

The task, presented on a computer (programmed in Visual Basic) used stimuli adapted from Treisman and Gelade (1980). 192 visual arrays were created. All arrays were comprised a black grid of 64 squares (8 by 8). The grid was presented as 392 x 392 pixels (9.3cm x 9.3cm). Grids contained either 1, 5, 15 or 30 stimuli, as shown in Figure 27.

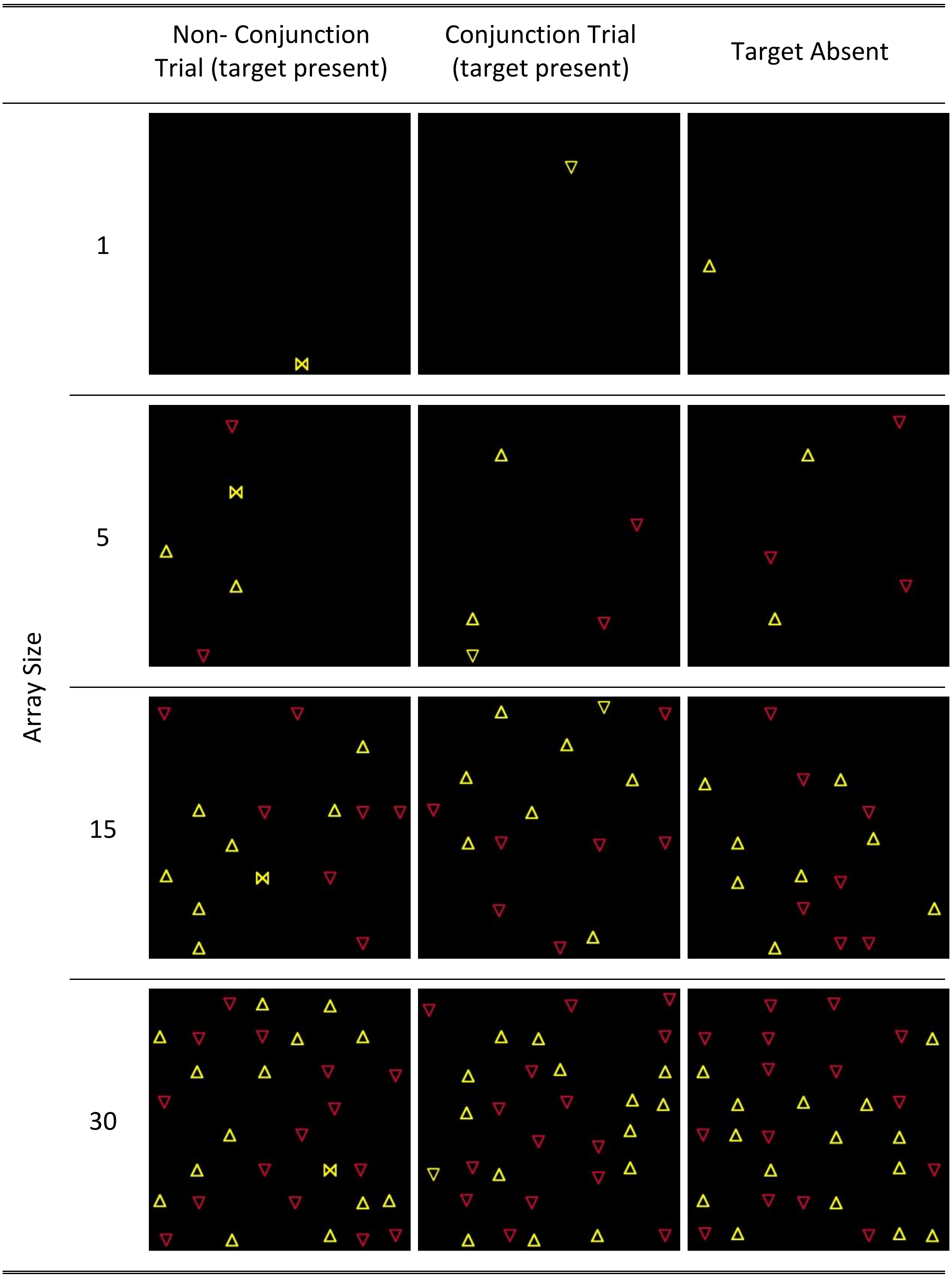

Figure 27: Grids used in Feature Search Task in Experiment 9, showing conjunction and non-conjunction trials for each array size.

All stimuli were brightly coloured, using the following colours; Red (204, 0, 51), Yellow (255, 255, 0) and Blue (0, 255, 255), as shown in Figure 28. Each stimulus was 0.46cm x 0.46cm. Equal numbers of each type of grid were created. As well as varying in the number of stimuli they contained, grids varied in the type of target presented in the grid and whether or not a target was presented. When a target was present, only one target was presented in the grid. The remaining stimuli were distractors. Two types of distractor were used; upward facing yellow triangles and downward facing red triangles.

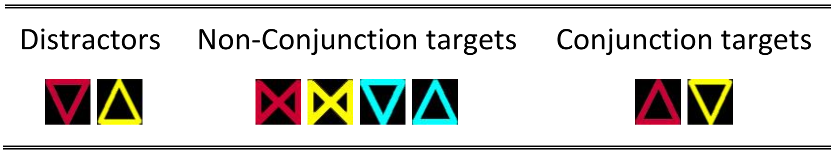

Figure 28: Stimuli used in the Treisman Feature Search Task.

Targets, presented on 50% of all trials, varied within trial type and across trial type. The experiment used two trial types. On non-conjunction trials, targets shared only one dimension in common with distracters. The targets used in non-conjunction trials were blue upward facing triangles, blue downward facing triangles, yellow kite shapes and red kite shapes. On conjunction trials, targets shared two dimensions in common with distracters. The targets used in conjunction trials were yellow downward facing triangles and red upward facing triangles.

For non-conjunction trials, for each of the 4 target stimuli, three visual search arrays were created for each size of grid. For each of the 2 target stimuli in conjunction trials, six visual search arrays were created for each size of grid. For every array created containing a target, a similar array was created which did not contain the target. The positions of the target and distracters in each array were varied using random number generation to plot the co-ordinates across the 8x8 grid.

4.5.1.3 PROCEDURE

At the test session participants completed the questionnaires (digit span, BDI then NEO-PI-R), as described in Experiment 8. In the task, participants were instructed that they would see 192 visual arrays and on each presentation would need to decide whether or not the described target was present. Participants were asked to respond as quickly and accurately as possible. Participants used the response keys “O” and “P” on their computer keyboard to respond. Participants were asked to use their right hand to respond with the index finger on “O” and their middle finger on “P”. Participants were asked to press “O” if the target was present and “P” if the target was absent. This instruction was repeated at the start of each trial block.

Trials were split into 16 blocks of 12 trials. In each block three trials were presented for each array size. The order of presentation was randomised. Within each block of trials the target was present on half of all trials. There were 2 blocks for each of the four disjunctive targets and 4 blocks for each of the two conjunctive targets. At the start of each block participants were shown the target they needed to search for and reminded: “Is this feature present in the following arrays? Press '**O**' if yes. Press '**P**' if no.”

500ms after the start of each trial, a fixation point was presented in the centre of the screen. The presentation of the fixation point was accompanied by a beep to focus the participant’s attention. The fixation point was presented for 500ms followed by a visual array. The array remained on the screen until participants started the next trial. Participants used the response keys on the keyboard to respond to whether or not the target was present in the visual array. On making a response participants were told whether or not their response was correct; “Correct” or “Incorrect” was written at the bottom of the screen. An on-screen button was presented to start the next trial. Response time was recorded in milliseconds as the time between the onset of the visual array and the participants’ response. Responses made before the visual array was presented were not encoded by the program. Accuracy of participants’ response was recorded by the program.

4.5.2 RESULTS

Participants’ response accuracy in completing the task was recorded and participants with low levels of accuracy were excluded. This step was taken as only response time to accurate trials was analysed, therefore, for participants with low accuracy, response time would be averaged across fewer trials, reducing the reliability. Participants whose error rate was two times the standard deviation above the mean for non-conjunction trials (mean = 2.18 (1.95)) or conjunction trials (mean = 10.29 (5.72)) were excluded. Following this criterion three participants were excluded; two participants from the high neuroticism group and one participant from the low neuroticism group.

Only response times to accurate trials were analysed. For each participant, response times for trials where they responded incorrectly were removed prior to average response times being calculated. Response times did not meet assumptions of normal distribution in most conditions for both low and high neuroticism groups. Following a logarithmic transformation, response times remained non-normally distributed in many conditions. Participants with response times of more than 3 standard deviations above the mean for any given condition were excluded. This excluded 4 participants; 3 from the high neuroticism group and 1 from the low neuroticism group. Following these exclusions, data were judged to be sufficiently normally distributed to allow for parametric tests. Though Shapiro-Wilk tests for normality remained significant for 10 of the 32 conditions, (lowest test statistic, W [20] = 0.817, p = 0.002), analysis of histograms and Q-Q plots suggested relatively normal distribution of data.

Figure 29, showing response time, indicates that the results replicated the standard feature search effect. On conjunction trials, when target detection required identifying a combination of two features, time taken to respond increased as array size increased. On non-conjunction trials, when detecting a target only required identification of one feature, time taken to respond was not influenced by array size.

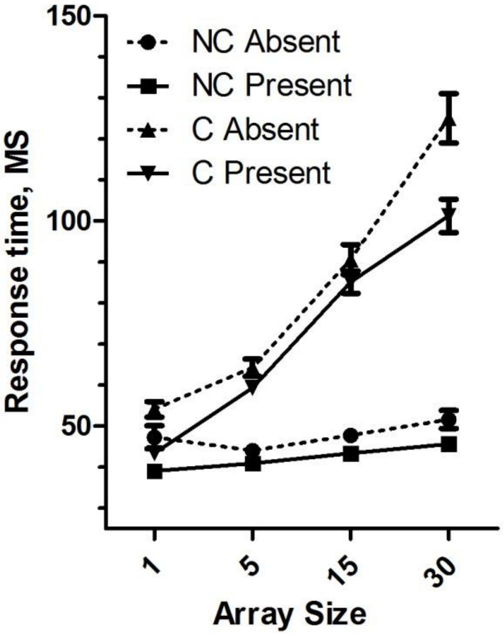

Figure 29: Response time by trial type across array size for Experiment 9, showing NC – Non Conjunction Trials and C – Conjunction trials.

A 2x2x4 way repeated measures ANOVA was conducted on response time with the factors of; conjunction (conjunction vs. no conjunction), target presence (present vs. absent), array size (1, 5, 15 or 30). All participants responded faster on non-conjunction than conjunction trials, (F [1, 41] = 669.71, p < 0.001), and faster on trials where the target stimulus was present, (F [1, 41] = 60.31, p < 0.001). Response times increased with array size on conjunction trials, but remained static for non-conjunction trials; there was a significant interaction between conjunction and array size (F [3, 123] = 274.97, p < 0.001). There was a significant interaction between array size and target presence (F [3, 123] = 9.28, p < 0.001). Post hoc analysis indicated that despite this interaction, there was a significant effect of target presence, with participants responding faster on trials when the target was present than when it was absent, at all array sizes, (Minimum F [1, 41] = 7.47, p = 0.008).

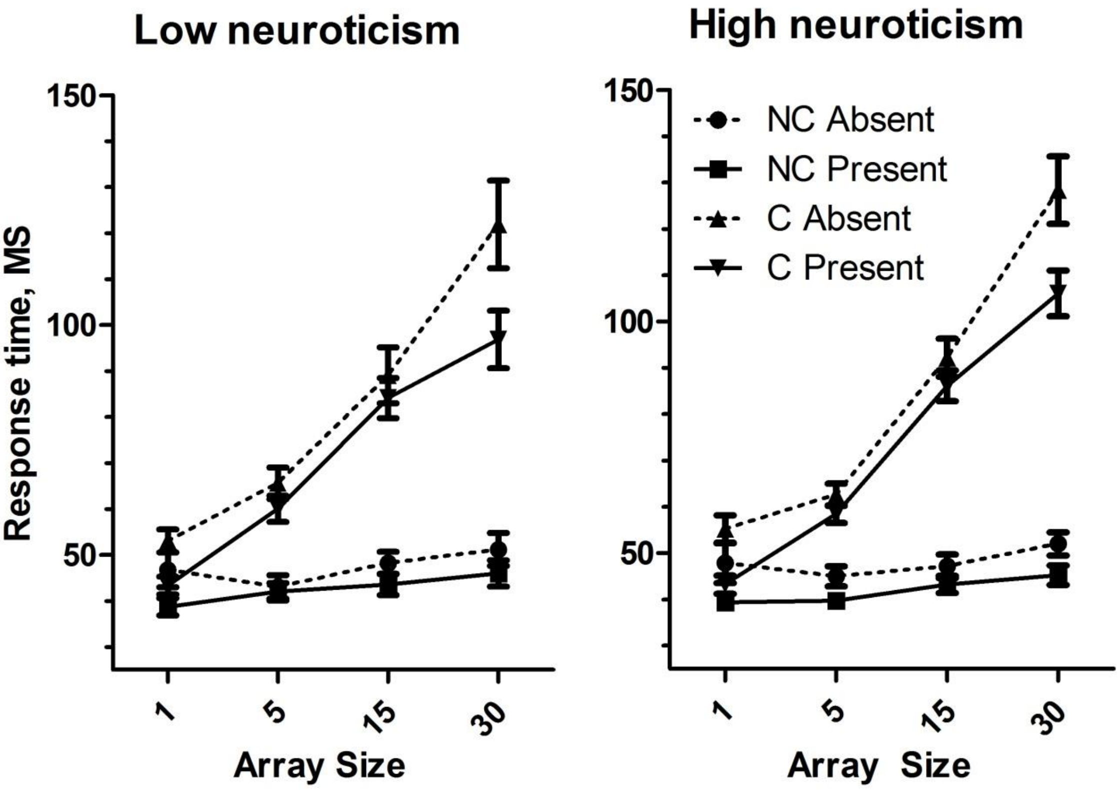

Figure 30: Response times for participants completing the Feature Search Task, Experiment 9, split by neuroticism

Figure 30 shows response time data separated by neuroticism group and suggests that the two neuroticism groups showed a similar response pattern. A 2x2x2x4 way ANOVA was conducted on response time with the factors of; conjunction (conjunction vs. no conjunction), target presence (target present vs. target absent), neuroticism group (low vs. high) and array size (1, 5, 15 or 30). This analysis revealed no significant interactions with neuroticism group. Neuroticism group did not interact with conjunction (F [1, 40] < 1, p = 0.466) or target presence (F [1, 40] < 1, p = 0.622). The interactions between neuroticism group, conjunction and array size (F [3, 120] = 2.07, p = 0.123) and neuroticism group, target presence and array size (F [3, 120] < 1, p = 0.850) were not significant. There was no significant four way interaction between these factors (F [3, 120] = 1.28, p = 0.284).

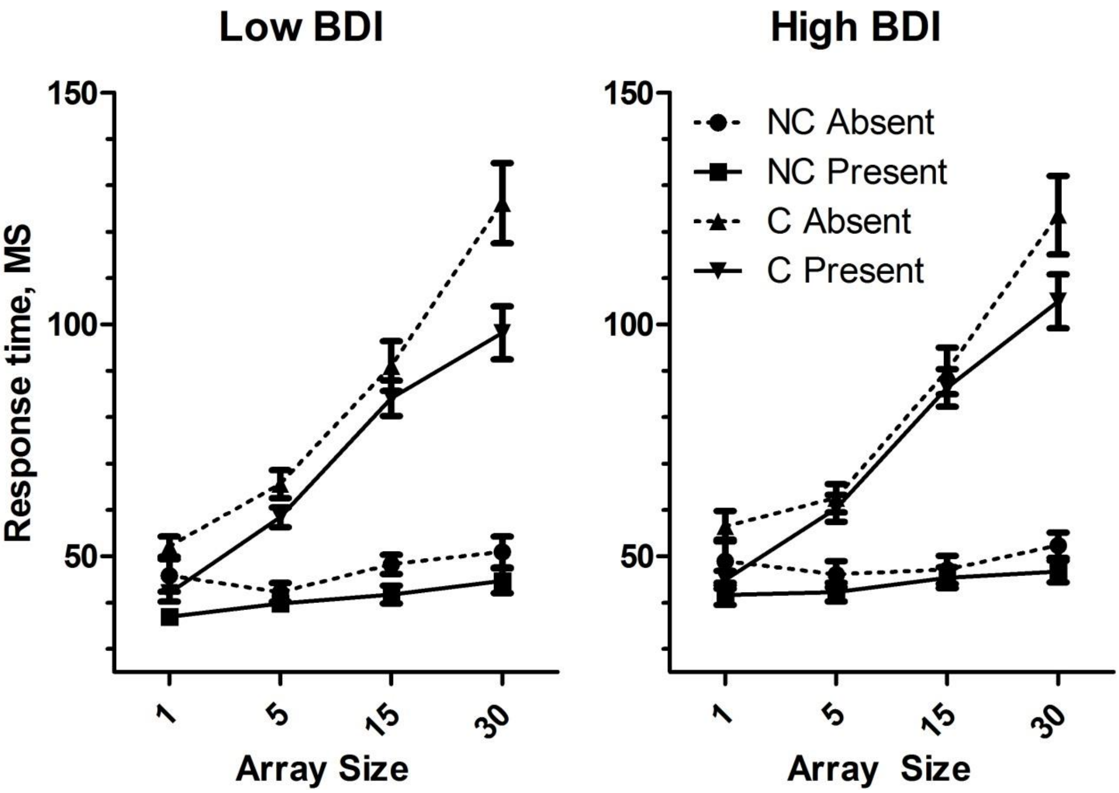

Figure 31: Response times for participants completing the Feature Search Task, Experiment 9, split by BDI score.

Figure 31 shows response time data separate by BDI group and illustrates a lack of substantive group differences in response time between BDI groups. A 2x2x2x4 way ANOVA was conducted on response time with the factors of; conjunction (conjunction vs. no conjunction), target presence (target present vs. target absent), BDI group (low vs. high) and array size (1, 5, 15 or 30). This analysis revealed no significant interactions with BDI group. BDI group did not interact with conjunction (F [1, 40] < 1, p = 0.493) or target presence (F [1, 40] = 2.06, p = 0.159). The interactions between BDI group, conjunction and array size (F [3, 120] < 1, p = 0.507) and BDI group, target presence and array size (F [3, 120] < 1, p = 0.782) were not significant. There was no significant four way interaction between these factors (F [3, 120] = 1.78, p = 0.160).

4.5.3 DISCUSSION

The aim of this experiment was to test whether dysphoria or neuroticism were associated with enhanced ability to identify conjunctions of features. The original feature search results were replicated; however, there was no significant effect of neuroticism or dysphoria. Neuroticism was not associated with improved ability to identify the conjunctions of co-occurring features. This appears to contrast the findings of Experiments 1 and 2 which identified an association between high neuroticism scores and ability to learn about conjunctions of co-occurring stimuli. Why would neuroticism be associated with improved learning about the conjunctions of stimuli but no improvement in conjunction identification?

The feature search task looks for rapid responses; it is possible that this time pressure results in the task picking up a different aspect of performance to the learning task. Both the EFT and the learning tasks, where group differences were identified, required participants to encode conjunctions between co-occurring features or stimuli and remember these for future use. The feature search task simply requires participant to identify conjunctions. It is thus possible that neuroticism is associated with an advantage in encoding and learning about conjunctions but not identifying conjunctions of features. To explore this possibility further it may be beneficial to test the association between neuroticism and ability to learn within compound associations independent from discrimination learning. Paired associate learning tasks

(Messbauer & de Jong, 2003; Williams & Pearlberg, 2006; Windfuhr & Snowling, 2001) in which participants are required to learn which stimuli go together, may provide a suitable platform for such assessment.

4.6 GENERAL DISCUSSION

The experiments presented in this chapter tested whether neuroticism or dysphoria, identified by high BDI scores, were associated with differences in the ability to process specific details, ignore context information, focus on goal relevant information or bind relevant features. Though performance on the EFT was associated with dysphoria, further exploration of why this association occurred did not reveal any substantive effects. Neither dysphoria nor neuroticism were associated with differences in the ability to process specific details, ignore context information or focus on goal relevant information, as measured through the Navon task, presented in Experiments 6, 7 and 8. Further, Experiment 9 revealed no association between neuroticism or dysphoria in terms of ability to identify conjunctions of features. The absence of effects in these perceptual tasks suggests that the group differences observed in the learning tasks presented in Experiments 1 and 2 may be the result of interaction between attention, learning and memory as opposed to a purely perceptual effect.

CHAPTER 5

5 A ROLE FOR ATTENTION INFLUENCING NON-LINEAR LEARNING?

Though global processing is associated with enhanced non-linear discrimination learning, the previous experiments failed to demonstrate a clear association between neuroticism and level of processing. Further, in Experiment 9, neuroticism did not appear to be associated with improved identification of feature conjunctions. This leaves unanswered the question of why neuroticism is associated with improved non-linear discrimination learning.

Processes of attention have a broad influence upon learning (Mitchell & Le Pelley, 2010). As neuroticism is associated with altered processes of attention (Fetterman & Robinson, 2011; Smillie et al., 2006; Wallace & Newman, 1998), variance in processes of attention may underlie to the relationship between neuroticism and non-linear discrimination learning. In particular, neuroticism appears to be associated with automatic orienting of attention towards salient information (Fetterman & Robinson, 2011; Wallace & Newman, 1998). For example, in completing a visual search task where participants were required to report whether one of three previously presented alphabetic characters was a target letter, high levels of neuroticism were associated with reduced response accuracy when distracters were present on the trial (Wallace & Newman, 1998). Distractors were discrepant from other alphabetic characters; comparable in size to the alphabetic characters, an arrow, a dollar sign the number 9 or a smiley face were presented as distractors. The high discrepancy should have made the distractors salient. While automatic orienting of attention towards salient information may impair task performance when the task requires controlled attention (Fetterman & Robinson, 2011; Wallace & Newman, 1998), enhanced ability to shift attention to salient stimuli should facilitate performance in certain associative learning tasks.

The process of shifting attention towards stimuli that are good predictors of significant events is fundamental to selective learning and behaviour (Mackintosh, 1974). Flexibly shifting attention facilitates ability to focus on a specific stimulus as distinct from the context in which it is presented. Indeed, one argument for why learning occurs more rapidly with intense stimuli suggests that intensity simply increases capacity for stimuli to be discriminated from the background context and this ability to discriminate stimuli from the background context facilitates learning (Logan, 1954; Perkins, 1953).

The strength with which associative learning occurs tends to increase with stimulus salience (Kamin, 1965; Kamin & Schaub, 1963). For instance, if two stimuli of different salience co-occur stronger stimulus-outcome associations should be acquired for the more salient stimulus, resulting in overshadowing of the less salient stimulus (Kamin, 1969; Mackintosh, 1971). It has been argued that learning also occurs more readily with stimuli that are good predictors while stimuli that are poor predictors loose ability to capture attention (Mackintosh, 1975).

An early attempt to explain the influence of attention was proposed by Mackintosh (1975) who suggested that learning about a stimulus was partially influenced by the salience of that stimulus. Stimulus salience may change with experience, increasing when a stimulus is predictive and decreasing when a stimulus is uncorrelated with an outcome. Latent inhibition is an example of such decline in stimulus salience following presentation of a stimulus that is uncorrelated with the outcome (Lubow, 2010; Lubow & Moore, 1959; Lubow et al., 1976). According to the Mackintosh model, learning depends on whether a stimulus is uniquely successful in predicting an outcome (Mackintosh, 1975). As such, change in stimulus salience may be influenced by the compound in which a stimulus is presented (Kamin, 1969; Le Pelley, Oakeshott, & McLaren, 2005; Rescorla & Colwill, 1983). For instance, in the case of blocking, if one stimulus (i.e., **A**) predicts the outcome, presenting a second stimulus (i.e., **X**) in compound with the predictive stimulus, is expected to reduce the salience of the second stimulus as, relative to the initial stimulus, it is a poor predictor of the outcome (Kamin, 1969).

Independent from the relationship between a stimulus and an outcome, stimulus salience is predicted to decrease with repeated exposure (Pearce & Hall, 1980). The Pearce-Hall (1980) model suggests that while reliable predictors of an outcome should be able to control behaviour, there is little point in allocating a large proportion of processing capacity for learning about events that are already involved in stable relationships. The salience of stimuli that are unreliable predictors of an outcome should remain higher than the salience of stimuli that are reliable predictors (Pearce & Hall, 1980). According to this model, a stimulus will capture attention to the extent that it is *not* an accurate predictor of an outcome. As such, the associability of a stimulus, that is the capacity for that stimulus to enter into new associations, should decline across a period of learning. Two approaches to information processing have been suggested to accommodate the apparent paradox of the stimuli capable of eliciting the strongest conditioned response having the least salience. Controlled processing strategies are used when a stimulus is novel or presented in a relatively unfamiliar context. This processing uses a limited capacity processor to allow subjects to learn about the stimulus and its relationship with an outcome. Once a subject is familiar with the task, an automatic processing strategy can be used.

Le Pelley (2004) identified a possible mechanism for reconciling these two approaches in a hybrid model. This mechanism depends upon acknowledging that the two models deal with different aspects of attention. The Mackintosh model addresses changes in the ability of a stimulus to capture attention dependent upon previous experience of the predictiveness of that stimulus relative to all other stimuli present. The Pearce-Hall model predicts the rate at which learning will occur once the stimulus has captured attention (Le Pelley, 2004; Mackintosh, 1975; Pearce & Hall, 1980). As such, the Mackintosh model predicts which stimuli will be learnt about while the Pearce-Hall model specifies the modulation of associative change that should occur depending on the exposure history of the stimulus.

Within the hybrid model, Le Pelley (2004) specifies two associability parameters; attentional associability (α) and salience associability (σ). Attentional associability, reflecting the Mackintosh model, measures the weight that should be afforded to a particular stimulus as compared to other stimuli. Attentional associability will determine which stimuli should have access to learning and which should not. Salience associability, reflecting the Pearce-Hall model, predicts the rate at which learning about each stimulus will proceed on the basis of the exposure history of that stimulus. Salience associability should govern how much is learn about a stimulus that has captured attention. Within the hybrid model, Le Pelley (2004) constrained attentional associability to vary between 0.05 and 1 and salience associability to vary between 0.5 and 1, such that while reductions in salience associability attenuate the rate of learning, they will not prevent learning. However, if a stimulus is not attended to, i.e., attentional associability is low, little processing will occur, regardless of the salience associability (Le Pelley, 2004).

Recently, Pearce and Mackintosh (2010) have adapted and clarified the Le Pelley (2004) hybrid model to give Equation 16.

Equation 16

$$\Delta V_A = \alpha_A \times \sigma_A \times \beta\,(\lambda - \Sigma V)$$[4]

Where $\Delta\alpha_A$ is positive if $|\,\lambda - V_A < \lambda - V_x|$ and $\sigma_A{}^{n+1} = \lambda^n - V_A{}^n$. Salience associability is calculated on the basis of previous trials, such that the salience associability on the subsequent trial (n + 1) is dependent upon the error term in the current trial (n). This change allows the salience associability of a stimulus to be

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[4] As detailed in previous chapters: V represents the associative strength of a stimulus; ΔV, the change in associative strength of a stimulus and ΣV the sum of associative strengths of all stimuli present on a trial. Λ is the total associative strength that a given outcome can support.

determined by how well it and it alone predicts its consequences. The relative validity of a stimulus is not important in calculating salience associability.

Changes in attention are predicted to have a wide influence on all learning situations, including the learning of non-linear discriminations, such as the negative patterning task presented in previous chapters. In the experimental designs reported in the previous chapters, participants have learnt about the outcomes associated with grids of coloured shapes. Although the shapes presented and the combinations in which those shapes were presented were predictive, many factors of the stimuli presented were not predictive. For instance, the global shape that the stimuli combined to form, was not predictive, neither was the proportion of the grid not containing shapes. Effective discrimination between predictive stimuli should be influenced by ability to identify which aspects of information presented on a trial were predictive and which were not.

Understanding individual differences in processes of attention has previously been beneficial in terms of advancing our understanding of information processing biases underlying psychopathology. For instance, there is some suggestion that individuals with depression may be less sensitive to contextual information (Msetfi et al., 2009; Msetfi et al., 2005). Disruptions in processes of attention have been widely explored in relation to schizophrenia and schizotypy and are associated with inability to redirect attention from irrelevant information. This is thought to contribute to aspects of information processing overload associated with the cognitive impairments that are characteristic of schizophrenia (Baruch et al., 1988; Gal et al., 2009; Gray et al., 1995; Haddon et al., 2011; Haselgrove & Evans, 2010; Jones et al., 1992b; Lubow, 2010;

Moran et al., 2003; Oades et al., 2000; Rascle et al., 2001; Williams et al., 1998). For instance, schizophrenia has been associated with an absence of blocking. In a blocking task individuals with schizophrenia will associate **X**, in an **AX** compound, with the paired outcome even if **A** already predicts this outcome (Haselgrove & Evans, 2010; Jones, Gray, & Hemsley, 1992a; Jones et al., 1992b; Jones et al., 1997; Moran et al., 2003; Moran et al., 2008; Oades et al., 2000).

In this chapter, I consider whether neuroticism is associated with alterations in processes of attention that might account for altered non-linear discrimination learning. A relative validity task was used to directly assess participants' tendency to shift attention away from non-predictive information. A perceptual learning paradigm was used to assess whether exposure to stimuli can differentially influence ability to discriminate between predictive and non-predictive perceptual information. Individuals with higher neuroticism scores may be expected to be more sensitive to the predictive validity and discriminative relevance of stimuli. Variation in either of these factors should contribute to an explanation of strong non-linear learning.

5.1 EXPERIMENT 10: SENSITIVITY TO THE PREDICTIVE VALIDITY OF STIMULI

The relative validity effect (Wagner, Logan, Haberlandt, & Price, 1968) demonstrated that a strong stimulus will block learning with a weaker stimulus. In their initial experiment, Wagner et al., (1968) trained two separate groups of animals with trials of two intermixed compounds, each composed of a target stimulus, **X** (a light) and one of two other stimuli, **A** or **B** (two auditory stimuli). One group was given a true discrimination in which all occurrences of the **AX** compound were paired with an outcome (i.e., **AX**+) while all occurrences of the **BX** compound were paired with no outcome (i.e., **BX**-). The second group was given a pseudo-discrimination where half of all **AX** and half of all **BX** trials were paired with an outcome. Both groups received the same exposure to **A**, **B** and **X** and in both groups **X** was paired with an outcome on 50% of trials. Despite the similar history of **X**, when it came to testing at the end of training, **X** was treated as more predictive of the outcome in the pseudo discrimination group than the true discrimination group (Wagner et al., 1968). Wagner et al., (1968) proposed that this occurred because **X** was relatively more informative in the pseudo-discrimination than the true discrimination.

This finding is effectively comparable to the observation made by Kamin (1969), in the initial blocking experiments. In the true discrimination the target stimulus, **X**, was always presented alongside perfect predictors of the presence or absence of the outcome. As such, learning with stimulus **X** was blocked. In contrast, in the pseudo discrimination condition, the target stimulus, **X**, was presented alongside non-predictive stimuli, allowing **X** to acquire associative strength. Furthermore, in the pseudo discrimination, though all stimuli are non-predictive, the outcome occurred in the absence of stimulus **A** and **B** but never in the absence of stimulus **X**. This may have been expected to increase the attention devoted to stimulus **X**.

In assessing sensitivity to the relative validity of stimuli as predictors of an outcome, the relative validity task has several procedural advantages over the blocking design (Baetu, Baker, & Murphy, 2005; Murphy, Baker, & Fouquet, 2001). For instance, unlike the blocking design, both conditions of the relative validity task are matched in terms of exposure to the stimuli (**A**, **B** and **X**) and in terms of exposure to the outcome.

To test individual differences in sensitivity to predictive stimuli in this experiment, a modified version of the relative validity design was used. This version of the design was used as it has previously been developed to test the relative validity effect with human participants (Baetu et al., 2005). This modification of the relative validity design in includes two true discriminations (TD1: **AX**-, **BX**-, 2CX+; TD2: **AX**+, **BX**+, 2CX-) and a pseudo discrimination (**AX**+/-, **BX**+/-, 2CX+/-; Murphy et al., 2001). In the TD1 condition there is one strong predictor of the outcome, **C**. In the TD2 condition there are two strong predictors of the outcome, **A** and **B**. In the TD1 condition, the strong stimulus (**C**) has a higher probability of occurring with the outcome than the target stimulus (**X**), and the outcome never occurs in the absence of either the strong predictor (**C**) or the target stimulus (**X**). This is the standard set up of the relative validity design. In the TD2 condition however, though the strong stimuli (**A** and **B**) are always followed by the outcome, they each only predict 50% of the occurrences of the outcome. In comparison, although the target stimulus (**X**) is only followed by the outcome 50% of the time, it always precedes the outcome.

The elemental model of learning (e.g., Rescorla & Wagner, 1972) is sensitive to both the proportion of stimulus presentations that are followed by an outcome and the total proportion of outcome occurrences that are predicted by a given stimulus (Baetu et al., 2005). As such, the model predicts that that target stimulus (**X**) should acquire less associative strength in the TD1 than TD2 condition. The configural model of learning (e.g., Pearce, 1987, 1994) makes a similar prediction. Judgements of the likelihood of outcome occurring following the target stimulus (**X**), assessed at test, are predicted to be driven by generalisation of associative strength from similar compounds. All compounds presented in this task contain **X** and one other stimuli. As such 50% of the associative strength of each compound is expected to generalise to **X**. In the TD1 condition, one compound (**CX**) is predictive of the outcome, while two compounds (**AX** and **BX**) are not. While in the TD2 condition, two compounds (**AX** and **BX**) are predictive of the outcome. Thus, assuming conditioning with the compounds reaches asymptote, the associative strength generalising to **X** should be considerably higher in the TD2 than TD1 condition.

Though the Baetu et al., (2005) experiment did not provide strong support for either of these predictions, participants' judgements of the likelihood of outcome occurring following the target stimulus (**X**) did tend towards differing between the two true discrimination conditions. The experiment also identified a strong relative validity effect; judgements of the likelihood of the outcome following the target stimulus (**X**) were higher in the PD condition than either TD condition, and within the PD condition, judgements of outcome likelihood following the target stimulus (**X**) were higher than judgements following any of the moderate predictors (**A**, **B** or **C**). This result is consistent with the idea that learning with **X** was blocked in the true discrimination conditions. On test trials, participants rated how likely it was that each stimulus (foods) caused the outcome (allergic reaction). In the PD condition participants on average did not state that **X** caused allergy, but rather concluded that **X** possibly caused allergy. In contrast in the true discriminations, participants stated that **X** did not cause allergy. The presence of other valid predictors of allergy allowed participants to reach the conclusion that **X** did not cause allergy. As such, learning with **X** was blocked.

Looking at individual differences in sensitivity to the relative validity of a stimulus, several results are possible. The relative judgements of **A**, **B** or **C** compared to **X** predicting the outcome in the PD condition may indicate differences in the sensitivity to the relationship between the stimuli and outcome. Specifically, in the PD condition, while the outcome never occurs in the absence of **X**, the outcome occurs in the absence of all the other stimuli. Individuals may differ in the extent to which they treat the total proportion of outcome predicted by a stimulus as informative, independent from the total proportion of stimulus presentations that are followed by the outcome. To the extent that participants judge the validity of a stimulus on the basis of pairings with outcome, independent from ability to predict outcome, participants should judge **X** to be significantly more predictive of the outcome than **A**, **B** or **C** in the PD condition.

Secondly, participants may differ in the extent to which they let the predictiveness of one stimulus block learning with a second stimulus. If individuals disregard the predictiveness of other stimuli when judging the predictiveness of **X**, they should be more likely to rate **X** as a possible cause of an outcome as opposed to reporting that **X** does not cause an outcome. In this case, the difference between judgements of outcome likelihood following **X** and stimuli consistently paired with outcomes in the TD conditions should be reduced.

High levels of neuroticism were associated with strong non-linear discrimination learning in Experiment 1 and 2. Performance in a discrimination learning task will be facilitated by ability to shift attention towards a predictive stimulus. If this mediates discrimination learning for the high neuroticism group, high levels of neuroticism may be expected to be associated with high sensitivity to the relative validity of stimuli, such that neuroticism is associated with a greater difference in judgements of the relationship between X and outcome between the true and pseudo discriminations.

5.1.1 METHOD

5.1.1.1 PARTICIPANTS

Twenty seven university students participated for course credit or were paid £5 for their participation. As described in Experiment 1, participants were categorised into groups of low and high neuroticism on the basis of a median split of neuroticism score, 79.70 (26.58)[5].

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[5] In previous studies neuroticism was measured using binary scoring, giving a much lower average score. Here neuroticism was measured on a likert scale. In this experiment, both measures were used, with a binary scoring system used to test neuroticism score prior to the experiment test sessions. The mean neuroticism score on this binary measure was 17.04, comparable to all other experiments presented in this thesis. The average neuroticism score, measured on a binary scale, for the low neuroticism group was 10.93 (3.41) and 23.92 (3.41) for the high neuroticism group. These averages however were calculated on the basis of partial data; approximately 20% of participants did not complete the neuroticism screening prior to the assessment.

Table 17: Demographics for participants completing Experiment 10, split by neuroticism group.

	Neuroticism group	
	Low	High
N	14	13
Neuroticism score (likert)	59.83 (7.10)	106.70 (20.74)
Age, years	19.50 (1.34)	19.60 (1.47)
Digit span, digits recalled	7.50 (0.52)	7.70 (0.48)
Gender (male)	3	1

Age (r = -0.16, p = 0.428) and digit span (r = 0.10, p = 0.658) did not correlate significantly with neuroticism score. Gender did not predict a significant difference in neuroticism score (U (4, 23) = 32.50, p = 0.356).

5.1.1.2 APPARATUS AND MATERIALS

All participants completed the digit span assessment of working memory (Lezak, 1995). In this experiment the NEO-PI-R (Costa & Mccrae, 1995) was conducted using a 5 point likert scale as described in Experiment 6.

The relative validity task was programmed on a PC computer using Visual Basic. Each discrimination involved four stimuli (**A**, **B**, **C** and **X**) paired in three compounds (**AX**, **BX**, and **CX**). Stimulus **X** was either: grapes, strawberry or carrot. Stimulus **A** was either: avocado, kiwi or tomato. Stimulus **B** was either: banana, lemon or peaches. Stimulus **C** was either: cherry, pepper or apple. Three sets of food were used so that all participants would learn about each of the 12 foods in one of the three conditions (TD1, TD2, or PD). The presentation of foods in conditions was counterbalanced. Food pairs were presented in white letters on black screen vertically above one another.

Two outcomes could occur; no allergic reaction or allergic reaction. On non-reinforced trials “no allergic reaction” was written in yellow at the bottom of the screen. On reinforced trials, “Allergic reaction” was written in red at the bottom of the screen.

5.1.1.3 PROCEDURE

Participants completed tasks in the following order; digit span, NEO-PI-R, relative validity task. In the relative validity task, each participant completed three conditions: true discrimination 1 (TD1), true discrimination 2 (TD2) and pseudo-discrimination (PD). The order of the conditions was counterbalanced. Each condition began with instructions, minimally modified from those used by Baetu et al., (2005);

> “Imagine that you are an allergist who is trying to determine the cause of an allergic reaction shortly after your patient eats dinner. You arrange that the patient eat particular foods at dinner over a series of evenings, and then report to you whether an allergic reaction followed. The results of the test series will be shown to you on subsequent computer screens. There will be one screen for each day of the allergy test. For each test, you will be asked to predict whether or not the foods eaten caused an allergic reaction. There is a scale from 1 to 9 on the keyboard, please use this to respond. If you think that the foods eaten do not cause an allergic reaction select numbers to the bottom of the scale. If you think foods eaten do cause an allergic reaction, select numbers to the top of the scale. After you make a response you will see whether or not the foods eaten caused an allergic reaction. The patient will be eating two of the following four foods each day: Avocado, Banana, Cherry and Grapes. After seeing all of the test results you will be asked to indicate how likely you think it is that each of the foods would cause an allergic reaction."

In each discrimination there were 9 **AX** trials, 9 **BX** trials and 18 **CX** trials, giving a total of 36 trials. In the TD1 condition, **AX** and **BX** trials were never followed by an allergic reaction whereas **CX** trials always were (**AX**-, **BX**-, 2**CX**+). In the TD2 condition **AX** and

BX trials were always followed by an allergic reaction, whereas **CX** trials never were (**AX**+, **BX**+, 2**CX**-). In condition PD, all compounds were followed by the occurrence of the outcome on 50% of the trials (**AX**+/-, **BX**+/-, 2**CX**+/-). Following each presentation, participants made a judgement of the likelihood that the foods presented caused an allergic reaction. Ratings were made using a scale from 1 to 9, where 1 meant the food presented definitely did not cause an allergic reaction and 9 meant it definitely did. Once a rating was made, participants were then presented with the outcome associated with that compound (i.e., allergic reaction or no allergic reaction).

After the 36 training trials, participants were presented with each food individually and asked to make a rating of the likelihood that this food alone caused allergic reaction. The order in which these four foods were presented was counterbalanced.

5.1.2 RESULTS

Throughout training participants provided judgements of likelihood of outcome occurring. In each condition **AX** and **BX** were treated identically. There was no significant difference in participants' judgements of the likelihood of outcome occurring after these two stimuli in the TD1 (F [1, 26] < 1, p = 0.397), TD2 (F [1, 26] < 1, p = 0.930) or PD (F [1, 26] < 1, p = 0.612) condition. Further, in no condition was there an interaction between judgements for these stimuli and neuroticism group (Maximum F [1, 26] = 2.22, p = 0.149). As such, through the analysis described below judgements of outcome likelihood following **AX** and **BX** have been combined.

After training, participants provided judgements of the likelihood that an individual stimulus would predict the occurrence of the outcome. As **AX** and **BX** received the same training, judgements following **A** and **B** should have been comparable in each condition. There was no significant difference in judgements of outcome likelihood following **A** and **B** in the TD1 (F [1, 26] < 1, p = 0.946), TD2 (F [1, 26] < 1, p = 0.445) or PD (F [1, 26] < 1, p = 0.411) condition and no significant interaction with neuroticism group (Maximum F [1, 26] = 3.97, p = 0.057). As such throughout analysis the average of judgements following **A** and **B** were considered.

During training, participants' judgements of allergy likelihood increased for stimuli consistently paired with allergy. A repeated measures analysis of variance (ANOVA), with the factors of; predicted outcome (allergy vs. no allergy), trial block (first vs. last), condition (TD1 vs. TD2 vs. PD) and neuroticism group (low vs. high) was conducted on judgement of outcome likelihood. There was a significant three way interaction between predicted outcome, trial and condition (F [1, 50] = 42.22, p < 0.001). The interaction between these factors and neuroticism was not significant (F [1, 50] < 1, p = 0.384). As would be expected following the trained contingencies, there was a significant interaction between predicted outcome and trial, with judgement of outcome likelihood increasing for compounds paired with allergy and decreasing to stimuli compounds paired with no allergy, in the TD1 condition (F [1, 25] = 110.85, p < 0.001) and the TD2 condition (F [1, 25] = 53.06, p < 0.001) but not the PD condition (F [1, 25] < 1, p = 0.873)

Figure 32 shows average ratings for **A**/**B**, **C** and **X** across each of the three conditions, split by neuroticism score. In general patterns of responding appear comparable between the low and high neuroticism groups.

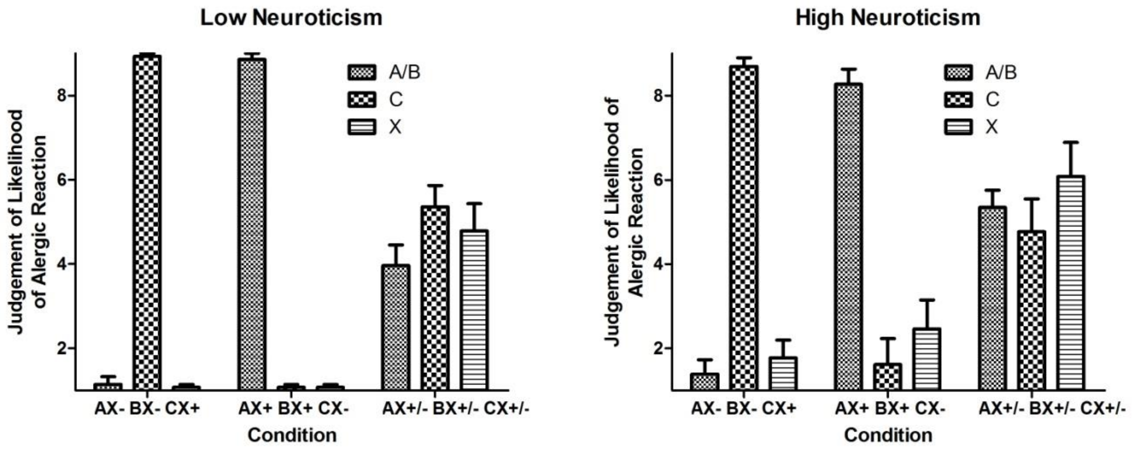

Figure 32; Judgements of the likelihood of allergic reaction, made for individual stimuli presented in test trials at the end of training. Judgements made by the low neuroticism group are shown left. Judgements made by the high neuroticism group are shown right. Experiment 10.

Across both true discrimination conditions stimuli consistently paired with the outcome during training were judged as significantly more predictive of the outcome occurring than stimuli paired with no outcome. A 2x2x2 way repeated measures ANOVA with the factors of; condition (TD1 vs. TD2), outcome predicted (allergy vs. no allergy) and neuroticism group (low vs. high neuroticism) confirmed that stimuli paired with the outcome were judged as significantly more predictive of the outcome than stimuli paired with no outcome (F [1, 25] = 1016.05, $p < 0.001$). There was no significant main effect of condition (F [1, 25] < 1, $p = 0.674$) and no significant interaction between condition and predicted outcome (F [1, 25] < 1, $p = 0.429$). This analysis did not reveal an interaction between neuroticism group and outcome predicted (F [1, 25] = 3.02, $p = 0.095$). There was no significant interaction between neuroticism group and condition (F [1, 25] < 1, $p = 0.950$) and no significant three way interaction between neuroticism group, condition and predicted outcome (F [1, 25] < 1, p = 0.429).

Ratings of the likelihood of outcome occurring following the target stimulus (**X**) were diminished in the two TD conditions relative to the PD condition for both groups. A repeated measures ANOVA on judgements of outcome likelihood following **X** revealed a significant main effect of condition (F [2, 50] = 50.17, p < 0.001). There was no significant interaction between neuroticism group and condition (F [2, 50] < 1, p = 0.654). Post hoc analyses indicated that ratings of the likelihood of outcome occurring following **X** were significantly higher in the PD condition than either the TD1 (t [26] = 8.18, p < 0.001) or TD2 (t [26] = 7.37, p < 0.001) conditions. Ratings of **X** in the two true discrimination conditions did not differ significantly (t [26] = 1.12, p = 0.272).

In the PD condition, participants in both low and high neuroticism groups gave moderate ratings to all stimuli. A repeated measures ANOVA comparing ratings to each stimulus (**A**, **B**, **C** and **X**), found no significant main effect of stimulus (F [3, 75] < 1, p < 0.462) and no significant interaction between stimulus and neuroticism group (F [3, 75] =2.42, p = 0.079). Pre-planned comparisons, justified to allow direct comparison to the findings of Baetu et al., (2005), did not reveal any significant differences between **X** and the other stimuli (Maximum F [1, 25] = 2.24, p = 0.147). These comparisons further did not reveal any significant interaction between neuroticism and specific differences between **X** and each of the other stimuli (Maximum F [1, 25] = 1.49, p = 0.234).

To further explore whether individuals differed significantly in their judgements of relative validity, two composite scores were calculated; a PD score and an **X** difference score. To calculate the PD score the average of participants' judgement of outcome likelihood following invalid predictors of the outcome (**A**, **B** and **C**) in the PD condition were subtracted from participants' judgement of outcome likelihood following the valid predictor of the outcome (**X**). To calculate the **X** difference score participants' average judgement of outcome likelihood following **X** in the true discrimination conditions (TD1 and TD2) were subtracted, from their judgement of outcome likelihood following **X** in the pseudo-discrimination.

Although participants did not systematically rate the valid stimulus higher than the invalid stimuli on in the pseudo-discrimination, there was considerable variability in participants' PD score; mean and standard error were -0.630 (0.60). This variability, however, did not correlate significantly with neuroticism score (r = -0.180, p = 0.368), age (r = 0.298, p = 0.131) or digit span (r = 0.234, p = 0.296). Similarly, the **X** difference score did not correlate significantly with any of these variables; neuroticism score (r = 0.185, p = 0.356), age (r = -0.253, p = 0.203) or digit span (r = -0.202, p = 0.368).

5.1.3 DISCUSSION

While this study found certain effects associated with blocking, it did not replicate the findings of Baetu et al., (2005). Baetu et al., (2005) found that participants' judgements of the likelihood of outcome occurring following the target stimulus X were higher in the pseudo-discrimination than either of the true discriminations. This effect was replicated. Baetu et al., (2005) also found that participants' judgements of the likelihood of outcome occurring following the target stimulus X in the pseudo-discrimination were higher than their judgements of the likelihood of outcome occurring following the other stimuli (A, B or C). The study presented here did not replicate this finding; there was no significant difference observed in participants judgements of the likelihood of outcome following any of the stimuli presented in the pseudo-discrimination.

This study did not demonstrate any effect of neuroticism upon judgement of stimulus validity. Other factors relating to individual differences, such as working memory capacity, measured using a digit span assessment, similarly did not correlate with measures of stimulus validity.

As observed by Baetu et al., (2005), this study confirmed that either using one or two strong predictors of an outcome reduces judgements of a moderate predictor. Contrary to the predictions of both elemental error prediction models (e.g., Rescorla & Wagner, 1972) and configural models (e.g., Pearce, 1987, 1994), judgements of the likelihood of outcome occurring following the target stimulus (**X**) were not higher in the TD2 condition than the TD1 condition. Though Baetu et al., (2005) found very tentative support for a difference in ratings of **X** in these conditions, the findings presented here provide no such support.

Contrasting the finding of Baetu et al., (2005), this study found no difference in participants' ratings of the likelihood of outcome occurring following the valid (**X**) and invalid (**A**, **B** and **C**) predictors in the pseudo-discrimination. This study used a larger sample size than the Baetu et al., (2005) experiment; 27 participants took part in this study as compared to the 24 participating in the Baetu et al., (2005) study. As such, the failure of this study to replicate findings from Baetu et al., (2005) is unlikely to be the result of this study lacking power. Procedural differences may have been important. Though much of the experimental design was identical to that used by Baetu et al., (2005), the training section of the experiment was presented as a learning task as opposed to simple exposure to stimulus-outcome pairings. In the Baetu et al., (2005) design, on each trial participants were shown two foods with the outcome ("allergic reaction" or "no allergic reaction") presented below the foods. In this task, participants were asked to judge whether the compound of foods presented predicted allergy or not. Participants were shown whether or not the combination of foods caused an allergic reaction only after they had provided their rating of how likely it was that the combination of foods would cause an allergic reaction.

Regardless of the differences in findings between this study and the Baetu et al., (2005) experiment, there were no systematic differences between low and high neuroticism groups and no indication that the other factors measured in this task (age and digit span) accounted for the variation in sensitivity to the predictive validity of stimuli. As such, this study provides no indication that neuroticism is associated with a difference in sensitivity to the predictive validity of stimuli.

5.2 EXPERIMENT 11: PERCEPTUAL LEARNING: PRE-EXPOSING THE STIMULI

Processes of attention play a prominent role in stimulus discrimination. To solve a non-linear discrimination, participants have to learn that one combination of stimuli is different from another combination of stimuli. This problem might be approached from two perspectives. First, if initial perception captures a cluster of distinct features, some of which occur across different combinations of stimuli, the task is to learn which combinations of features go together. Second, if initial perception captures a global representation, within which separate features are not initially discriminated, distinguishing one global representation from another similar representation might be dependent upon identifying the separate and distinguishing features from the compound. Up until now, I have focused heavily on the first of these possibilities. Here I consider the process of discriminating between two similar complex configurations in terms of breaking the configuration down to perceive the distinguishing features. This process may be compared to perceptual learning, analysis of which may clarify individual differences in discrimination learning.

Perceptual learning occurs when we are provided with the opportunity to compare stimuli or combinations of stimuli (Artigas, Chamizo, & Peris, 2001; Blair & Hall, 2003a, 2003b; Hall, 1991; Honey & Bateson, 1996; Honey, Bateson, & Horn, 1994; McLaren, Kaye, & Mackintosh, 1989; Mondragon & Hall, 2002; Mundy, Dwyer, & Honey, 2006; Mundy, Honey, & Dwyer, 2009; Sanjuan, Alonso, & Nelson, 2004; Scahill & Mackintosh, 2004; Symonds & Hall, 1995). Associative and non-associative explanations have been developed to account for this process.

In terms of non-associative accounts, Gibson’s theory of differentiation suggests that mere exposure to stimuli is capable of producing a change in the way that a stimulus is perceived (Gibson, 1969). Exposure to a pair of stimuli is suggested to increase the effectiveness of distinguishing stimulus features; especially if the stimuli are presented in a format that allows comparison, for instance, intermixed presentation (Gibson, 1969). Saksida (1999) developed the Gibsonian idea of differentiation into a non-associative model of perceptual learning. This model takes a network approach in which input feeds into a layer of competitive units (Saksida, 1999). A competitive-learning mechanism allows the weights of these units to approximate the pattern of input activation over repeated presentation of the stimulus. The competitive learning mechanism, adopted in this model, is based on a standard technique for pattern classification in machine learning (Kohonen, 1984; Rumelhart & Zipser, 1986). This algorithm exploits the statistical properties of stimuli and over time, as the system gains more samples, the statistical classifications become more reflective of the parameters of the actual population being sampled. This mechanism is assumed to result in an expansion of the area of the competitive layer that is devoted to the stimuli being discriminated (Saksida, 1999).

The associative accounts that have been developed assume that a trade-off between two different processes occurs during repeated exposure to stimuli (Artigas et al., 2001; Bennett, Scahill, Griffiths, & Mackintosh, 1999; McLaren et al., 1989; Mondragon & Murphy, 2010; Mundy et al., 2006). As described in the above discussion of attention, repeated presentation of a stimulus results in a reduction in stimulus associability. If stimuli are consistently non-predictive, participants will cease to attend to the stimuli all together (Lubow & Moore, 1959; Lubow et al., 1976). This process, termed latent inhibition, can account for a degree of perceptual learning (McLaren et al., 1989; McLaren & Mackintosh, 2000). When similar stimuli are presented repeatedly, the features that stimuli share in common will be presented most often. As such, these features should be most affected by a reduction in attention. For instance, consider repeated presentations of **AX** and **BX**. The common feature, **X**, will be presented twice as often as either **A** or **B**. This should cause **X** to accrue twice as much latent inhibition as either of the unique features (McLaren et al., 1989; McLaren & Mackintosh, 2000). As such, attention should shift away from **X** and towards **A** and **B**. This shift in attention away from common features and towards unique or distinguishing features should facilitate discrimination learning.

The improvement in discrimination learning following stimulus pre-exposure is dependent on the similarity between the stimuli (McLaren et al., 1989; McLaren & Mackintosh, 2000; Mclaren et al., 2010; Scahill & Mackintosh, 2004). Repeatedly presenting stimuli without outcomes should reduce later capacity to learn about the stimuli in general and therefore the benefit of improving ability to discriminate between stimuli must be greater than the cost of reduced associability (McLaren et al., 1989; McLaren & Mackintosh, 2000; Mclaren et al., 2010; Scahill & Mackintosh, 2004). This cost-benefit trade-off is greatest when stimuli are similar.

The second associative mechanism proposed to contribute to perceptual learning becomes apparent when we consider some of the illustrations of perceptual learning. Scahill and Mackintosh (2004) manipulated the difficulty of a flavour discrimination. Rats needed to discriminate between saline and sucrose. The saline and sucrose were either presented alone (i.e., **A** or **B**), in compound with weak lemon flavour (i.e., **Ax** or **Bx**) or in compound with strong lemon flavour (i.e., **AX** or **BX**). The lemon flavour acted as a common element. The group trained with the weak common element showed stronger discrimination learning than the group trained with the strong common element. Weakening the common element, however, was more effective than simply removing the common element. While reducing attention devoted to common elements is an important function of stimulus pre-exposure, improving discrimination, the common element plays a valuable role in facilitating discrimination.

Previous experiments looking at the influence of blocked as opposed to intermixed stimuli pre-exposure have supported the role of a common element in facilitating perceptual learning. For instance, pre-exposing two compounds in an intermixed fashion (i.e., **AX**, **BX**, **AX**, **BX**) facilitates greater improvement in discrimination than presenting the same stimulus compounds in blocks (i.e., **AX**, **AX**, **BX**, **BX**; (Honey & Bateson, 1996; Honey et al., 1994; Mondragon & Hall, 2002; Sanjuan et al., 2004; Symonds & Hall, 1995). This effect has been accounted for in terms of mutual inhibition and is dependent on the presence of a common element (McLaren et al., 1989; McLaren & Mackintosh, 2000).

The theory of mutual inhibition makes two assumptions. First, within-compound associations form between stimuli presented in compound (McLaren et al., 1989; McLaren & Mackintosh, 2000). For instance, when **BX** is presented links form between **B** and **X** such that when **X** is presented on other trials **B** will be associatively evoked. Second, according to Wagner's the SOP model of learning (Brandon, Vogel, & Wagner, 2003; Vogel, Brandon, & Wagner, 2003; Wagner, 1981), associatively evoked representations behave differently to representations activated by the presence of a stimulus. For instance, if **A** and **B** are both presented, associations will form between representations of **A** and **B** such that on trials where **A** is presented, the representation of **B** will be evoked. If however, **A** is presented while the representation of **B** is associatively evoked in the absence of **B**, the association formed between the representation of **A** and **B** should be inhibitory (Brandon et al., 2003; Vogel et al., 2003; Wagner, 1981).

Intermixed presentation of **AX** and **BX** allows this process of mutual inhibition so that **A** and **B** inhibit each other (McLaren et al., 1989; McLaren & Mackintosh, 2000; Mclaren et al., 2010). These mutually inhibitory links cannot be formed during blocked pre-exposure because there is only scope for inhibition to develop in one direction. In blocked pre-exposure associative links can develop between **A** and **X** on **AX** trials which allow for **A** to be associatively evoked on **BX** trials, facilitating an inhibitory association to develop between **B** and the associatively evoked **A**. There is, however, no scope for this to occur in reverse with **A** forming an inhibitory association with the associatively evoked stimulus **B**. This difference has been suggested to account for the difference in effect of block and intermixed pre-exposure (Mclaren et al., 2010; Mondragon & Murphy, 2010; Sanjuan et al., 2004).

Increased capacity to engage in perceptual learning should reduce the perceived similarity between stimuli compounds, facilitating non-linear discrimination. Enhanced ability to engage in perceptual learning is thus one possible explanation for strong non-linear discrimination observed in individuals with high neuroticism scores.

The following experiment tested the hypothesis that neuroticism is associated with strong perceptual learning. Specifically, the experiment tested whether, given the opportunity for perceptual learning, individuals with high neuroticism scores show a greater improvement in discrimination learning than individuals with low neuroticism scores.

During perceptual learning, however, two factors might be at work. The process of increased differentiation between similar stimuli was described above. A second factor, unitization, might also influence performance. McLaren et al., (1989, 2000) described unitization as the binding of co-occurring stimuli. Thus improved performance after an opportunity to engage in perceptual learning may occur because of improved ability to differentiate between similar stimuli compounds due to latent inhibition of common elements and mutual inhibition of unique elements or may be the result of improved ability to encode and remember the co-occurrence of stimuli.

In the experiments presented here these two factors were compared using two forms of stimulus pre-exposure; a feature and a configuration pre-exposure. In the feature pre-exposure, all of the stimuli were presented during the pre-exposure phase but were not presented in the same configurations that would later be trained (i.e., if an individual was later learning **A**+, **BC**+, **ABC**-, **D**-, **EF**-, **GHI**+ the following might be pre-exposed: **B**, **AC**, **BCD**, **E**, **FG**, **AHI**). Latent inhibition of common elements and mutual inhibition through this condition should help reduce attention devoted to context or periphery information, facilitating later discrimination. Specifically, pre-exposure should help participants differentiate between relevant stimuli and irrelevant context information. If unitization occurred through this condition, however, it should only impair later discrimination learning, as the features combined into a single unit were not relevant combinations for learning. In the configuration pre-exposure condition, the same configurations were presented in the pre-exposure phase and the discrimination task. Through this task, latent inhibition of common elements and mutual inhibition as well as unitization should contribute to improve discrimination.

If individuals differ only in processes of accrual of latent inhibition to common elements or mutual inhibition, pre-exposure should affect later learning, regardless of whether pre-exposure occurred in a feature or configuration condition. If individuals differ in the process of unitization, there should be a greater individual difference following the configuration condition than the feature condition.

The challenge in any perceptual learning design is to pre-expose stimuli in a manner that ensures that participants attend to the stimuli while receiving no information about the stimuli which could relate to the later discrimination. One way to facilitate this is to present the stimuli as a prominent but redundant component of a different task. For instance, the stimuli might be presented as a “mask” in a different task (Mclaren et al., 2010). In this experiment, pre-exposure to stimuli was provided by presenting the stimuli as “masks” for the Navon task.

5.2.1 METHOD

5.2.1.1 PARTICIPANTS

Eighty six university students participated for course credit or were paid £5 for their participation. As described in Experiment 1, participants were categorised into low and high neuroticism groups on the basis of a median split of neuroticism score, 18.13 (7.07). Forty four participants completed a discrimination task following a pre-exposure condition (feature condition = 21, configuration condition = 23). Thirty nine participants completed the discrimination task following no pre-exposure condition. Average neuroticism score did not differ significantly between the three conditions (F [2, 83] < 1, p = 0.749). Demographics for these participants are shown in Table 18.

Table 18: Demographics for participants completing Experiment 11.

	No Pre-exposure		Pre-exposure			
	Low neuroticism	High neuroticism	Low neuroticism		High neuroticism	
			Configuration	Feature	Configuration	Feature
N	22	18	11	13	13	9
Neuroticism score	12.73 (3.28)	26.14 (6.90)	14.36 (2.66)	13.31 (3.04)	22.62 (5.80)	23.33 (4.00)
Digit span, digits recalled	7.40 (0.82)	7.63 (0.50)	7.50 (0.53)	7.54 (0.52)	7.36 (0.67)	7.38 (0.52)
Age, years	20.50 (2.18)	19.67 (2.11)	19.27 (1.19)	20.31 (1.11)	20.54 (1.45)	21.11 (1.05)
Gender (male)	5	4	4	6	3	5

There was no correlation between neuroticism score and age (r = -0.001, p = 0.994) or digit span (r = -0.032, p = 0.780). There was no significant variation in neuroticism scores between male and female participants (U (27, 59) = 728.50, p = 0.606). Univariate analysis of variance with the factor of condition (no pre-exposure, configuration pre-exposure, feature pre-exposure), was used to assess whether demographic variables differed between the experimental conditions. Participants' digit span, neuroticism score, age and gender, did not vary significantly across the three conditions (Maximum F [2, 84] = 2.46, p = 0.092).

5.2.1.2 APPARATUS

All participants completed the digit span assessment (Lezak, 1995) and the neuroticism subsection of the NEO-PI-R (Costa & Mccrae, 1995). Shape stimuli in a negative patterning task were used to test discrimination learning, as described in Experiment 1. The Navon task, as described in Experiment 3, was used as a cover design to present stimuli during the pre-exposure phase of this experiment.

5.2.1.3 PROCEDURE

During the test session participants completed tasks in the following order; digit span, NEO-PI-R, Navon task and then the negative patterning task. Participants in the no pre-exposure condition completed the negative patterning discrimination immediately after completing the initial questionnaires.

To provide exposure to the stimuli used in the negative patterning task, the masks presented in the Navon task were replaced by the stimuli used in the negative patterning task. A different stimulus was used on each trial and the order in which these stimuli were presented was random. The stimuli were presented for 500ms, regardless of the time that it took participants to respond in the Navon task. Participants were shown each stimulus compound 10 times during the pre-exposure phase.

Participants in the pre-exposure conditions completed one of two conditions; configuration pre-exposure or feature pre-exposure. In the configuration condition the stimuli shown during the Navon task were identical to those participants would learn about in the negative patterning design. In the feature condition, the stimuli that participants were shown in the Navon task were similar to those they would learn about but not identical. Specifically, the stimuli used in the feature condition were stimuli combinations from a different counterbalancing rotation to the one that the participant would complete in the negative patterning discrimination. As such these participants saw all of the stimuli features that they would go on to learn about but the stimuli were presented in different combinations to those shown during the negative patterning task. For instance, if in the negative patterning task participants learnt about **A** / **BC** / **ABC** and **D** / **EF** / **GHI** they might be shown **B** / **CD** / **BCD** and **E** / **FG** / **AHI** during the Navon task. Other than change in the mask presentation, the Navon task was conducted as described in Experiment 3. The negative patterning task was completed as described in Experiment 1.

5.2.2 RESULTS

As described in Experiment 1, participants provided judgements of the likelihood of outcome occurring on each trial of the discrimination task. Trial blocks were calculated, as described in Experiment 1. As described in previous experiments, participants were excluded from the analysis if, at the end of the linear discrimination training, they continued to judge stimuli predictive of an outcome as less predictive of outcome that stimuli not predictive of outcome. This excluded one participant from the configuration pre-exposure condition.

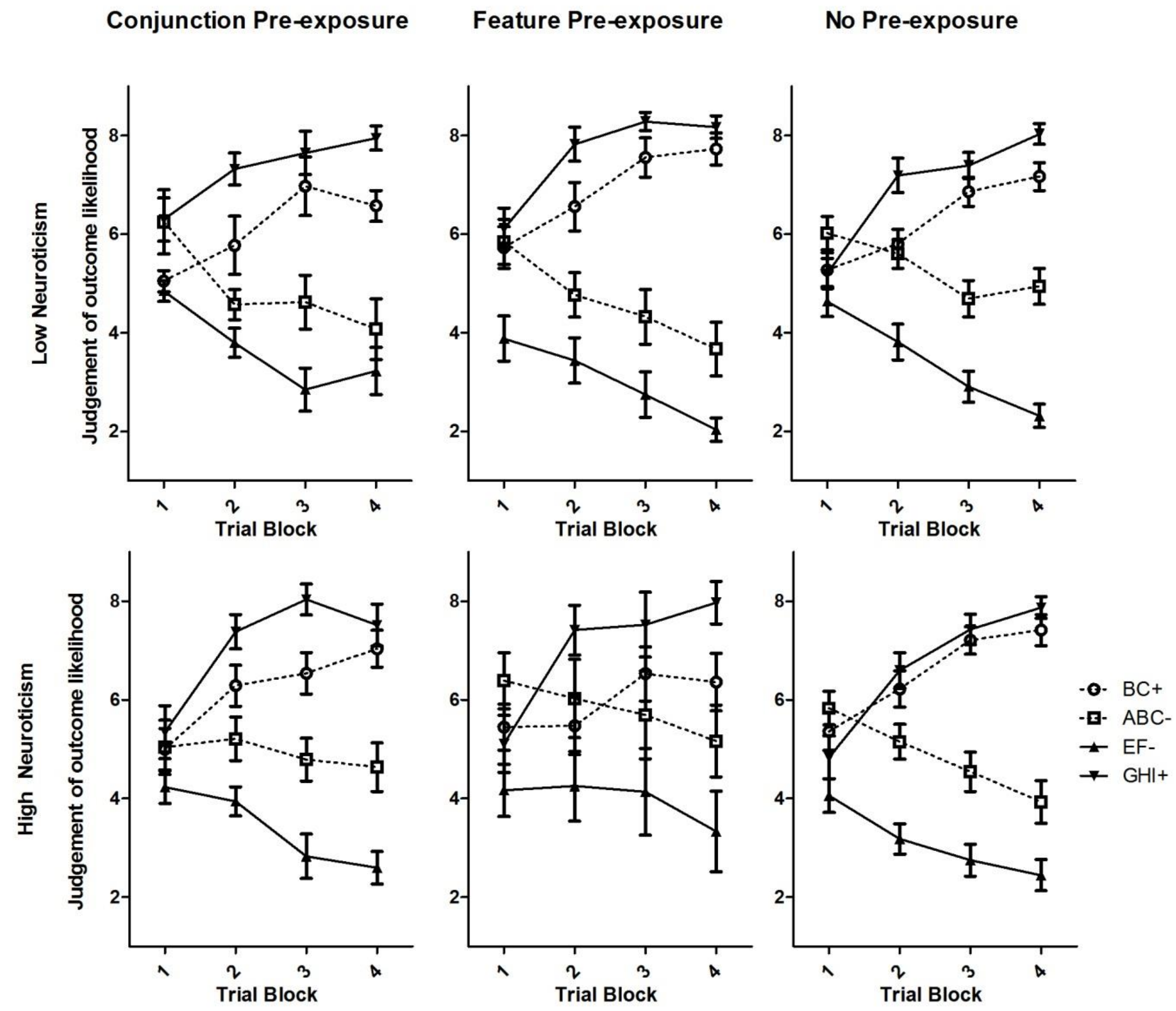

Figure 33: Judgements of the likelihood of the outcome occurring through negative patterning training following configuration pre-exposure, feature pre-exposure or no pre-exposure

Influence of perceptual learning was expected to be most apparent in the early stages of discrimination. As such, in contrast to previous experiment using the negative patterning task (e.g., Experiment 1), all trial blocks were analysed. Figure 33 shows judgements of the likelihood of the outcome occurring through negative patterning training and suggests that while pre-exposure may have improved discrimination learning for the low neuroticism group, it possibly impaired discrimination learning for the high neuroticism group.

A 2x2x3x4 way ANOVA was conducted on discrimination scores, calculated as described in Experiment 1, with the within subjects factors of discrimination (linear vs. non-linear) and trial block (1 – 4) and the between subjects factors of neuroticism group (low vs. high) and pre-exposure (features vs. configurations vs. no pre-exposure). There was a significant main effect of discrimination (F [1, 79] = 138.66, p < 0.001), with participants showing stronger stimulus discrimination in linear than non-linear condition. This effect of discrimination did not increase substantially over training; the interaction between stimulus discrimination and trial blocks was only marginally significant (F [3, 237] = 2.70, p = 0.053). Neither neuroticism group nor pre-exposure interacted significantly with discrimination task (Maximum F (2, 79) < 1, p = 0.424). Neither neuroticism group nor pre-exposure interacted significantly with the interaction between discrimination and trial block (Maximum F (3, 237) < 1, p = 0.569). There was, however, a significant interaction between pre-exposure and neuroticism group (F [2, 79] = 5.30, p < 0.01).

Post hoc analysis (with Bonferroni correction applied to control for multiple comparisons, significance level is 0.025) revealed a significant main effect of pre-exposure for the low neuroticism group (F [2, 42] = 5.05, p = 0.011); discrimination scores were significantly higher following the feature pre-exposure than no pre-exposure (F [1, 33] = 9.01, p = 0.005) but not configuration pre-exposure (F [1, 21] = 4.70, p = 0.042). There was no significant difference in discrimination scores following configuration pre-exposure compared to no pre-exposure (F [1, 30] < 1, p = 0.664).

Pre-exposure condition did not interact with discrimination (F [2, 42] < 1, p = 0.925) or trial block (F [6, 126] < 1, p = 0.912) and there was no significant three way interaction (F [6, 126] = 1.18, p = 0.324).

For the high neuroticism group there was no significant main effect of pre-exposure condition (F [2, 37] = 1.28, p = 0.229). Further pre-exposure condition did not interact with discrimination (F [2, 37] = 1.00, p = 0.376) or trial block (F [6, 111] = 1.05, p = 0.387) and there was no three way interaction (F [6, 111] < 1, p = 0.699).

5.2.3 DISCUSSION

This study tested whether neuroticism was associated with a difference in the effectiveness of stimulus pre-exposure on subsequent discrimination learning. Three pre-exposure conditions were compared: no pre-exposure, feature pre-exposure and configuration pre-exposure. Though participants showed stronger discrimination learning in the linear than non-linear tasks, pre-exposure to the stimuli, either in the feature or configuration condition, did not have a substantive influence on subsequent discrimination learning.

Analysis indicated an interaction between neuroticism and pre-exposure condition. Stimulus pre-exposure had no significant influence upon subsequent discrimination for the high neuroticism group. For the low neuroticism group, however, feature pre-exposure and only feature pre-exposure, improved subsequent discrimination. This improvement was consistent across both linear and non-linear conditions and did not vary across trial blocks.

It was expected that feature pre-exposure should improve discrimination by providing opportunity for mutual inhibition of unique features and latent inhibition of common features. However, configuration pre-exposure also provided opportunity for these processes to occur, thus we may have expected that both feature and configuration pre-exposure conditions should have improved subsequent discrimination. As configuration pre-exposure presented the stimulus configurations subsequently used in the discrimination task, the pre-exposure may have results in a decline in associability, impairing subsequent discrimination. As the feature pre-exposure condition did not present the precise configurations used in the discrimination task, the pre-exposure phase may have permitted latent inhibition to accrue to the context information, common across all trials, while not resulting in a decline in associability of the compound to be discriminated. A decline in associability following configuration pre-exposure would have been most likely to occur if similarity between compounds was relatively low. Further exploration, varying the similarity of compounds, is necessary to test this hypothesis for why feature pre-exposure was more effective in improving discrimination than configuration pre-exposure.

This effect was not apparent in the high neuroticism group. For this group, discrimination following either the feature or configuration pre-exposure condition did not differ significantly from the no-pre-exposure condition. This indicates that for the high neuroticism group feature pre-exposure did not improve subsequent discrimination, suggesting that latent inhibition to common elements may not have occurred. One possible interpretation of this result suggests that the high neuroticism group may have been less inclined to adjust the perceived associability of stimuli and change their allocation of attention following experience of stimuli under conditions of no outcome presentation. Though further experiments are required to test this possibility, it relates to previous work conducted with individuals of low mood which suggested that dysphoria, a state highly correlated with neuroticism (Kendler, Gatz, Gardner, & Pedersen, 2006; Kendler et al., 2004; Kendler, Neale, Kessler, Heath, & Eaves, 1993), is associated with reduced sensitivity to information presented in no-action-no-outcome conditions (Msetfi et al., 2005).

The results of this study do not suggest that neuroticism is associated with increased capacity to engage in perceptual learning. In fact, the results suggest that, at least in conditions where stimuli are presented in the absence of the associated outcome and under conditions that do not directly require participants to engage with the stimuli, higher neuroticism scores may be associated with reduced tendency to engage with perceptual learning.

It should be noted, however, that the stimuli used in this experiment were relatively simple and similar compounds (i.e., BC and ABC) only shared two out of three stimuli in common. As the compounds were combinations of shapes, the differences between the compounds should have been readily perceptible. McLaren et al., (2010) use stimuli which, prior to pre-exposure, cannot be differentiated. Further experiments conducted with complex stimuli may be beneficial to fully understand individual differences in perceptual learning. Such experiments may benefit from using a simpler task to test the effect of stimulus pre-exposure, such as a categorisation task (Mclaren et al., 2010), as it is possible that the inherent complexity of the negative patterning task masked effects of pre-exposure.

5.3 GENERAL DISCUSSION

The experiments presented here tested individual differences in processes of attention, specifically assessing sensitivity to the relative validity of stimuli and the opportunity for perceptual learning. Although Experiment 11 provided a tentative indication that neuroticism may be associated with reduced sensitivity to information presented under no-action – no-outcome conditions, there is minimal evidence from these studies of any associations between neuroticism and biases in attention that would account for the differences in non-linear discrimination learning observed in Experiments 1 and 2.

CHAPTER 6

6 CONCLUSION

6.1 SUMMARY OF FINDINGS

The experiments presented in this thesis tested whether individuals differ in their ability to combine stimuli and learn about combinations of stimuli as distinct configurations. Considerable individual difference in ability to engage in configural learning was observed. The ability to learn a non-linear discrimination was found to be related to performance on the Navon hierarchical processing task. Specifically, individuals showing a global processing bias on the Navon task showed stronger non-linear discrimination learning than individuals showing a local processing bias. Individuals showing a global processing bias identified globally presented target letters faster than they identified the small letters (i.e., specific details) composing the global letter. This novel finding moves us closer to understanding the mechanisms underlying individual differences in non-linear discrimination learning.

Though stress is associated with a narrowing of attention to focus on specific details (Christianson et al., 1991; Loftus et al., 1987), neuroticism, a personality trait associated with high levels of distress (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004; Suls & Martin, 2005; Uliaszek et al., 2010), was not associated with a local processing bias on the Navon task. Individuals with high levels of neuroticism were no faster responding to specific details than individuals with low levels of neuroticism. Despite the lack of interaction between neuroticism and ability to process specific details, neuroticism was associated with ability to learn a non-linear discrimination. Individuals with high levels of neuroticism were observed to show stronger non-linear discrimination learning than individuals with low levels of neuroticism.

Experiments 6, 8, 9, 10 and 11 tested factors that may have contributed to the association between neuroticism of strong non-linear discrimination learning. Analysis of performance of individuals with high levels of neuroticism, in completing the Navon task, did not support the hypothesised association between neuroticism and enhanced processing of specific details. Further, in Experiment 8 there was no indication of an association between neuroticism and enhanced goal directed processing or improved ability to ignore conflicting context information when identifying specific details. Though high levels of arousal have been associated with enhanced binding of relevant features (Mather & Sutherland, 2011), in Experiment 9, individuals with high neuroticism scores did not out-perform individuals with low neuroticism scores when searching for feature conjunctions, a task thought to be dependent on ability to bind relevant features. Altered salience attribution may have contributed to changes in ability to learn about combinations of stimuli, however in Experiment 10, neuroticism was not assoicated with any alteration in sensitivity to the relative validity of stimuli and in Experiment 11, no substantive differences in sensitivity to stimulus pre-exposure were observed.

6.2 INDIVIDUAL DIFFERENCES IN NON-LINEAR DISCRIMINATION LEARNING

The observation of individual difference in the ability to learn a non-linear discrimination has important implications for models of associative learning. Many associative learning experiments look at the average performance in a learning task, but the results presented here suggest that there is considerable individual difference in human learning. Failure to consider variability in human performance on learning tasks introduces the possibility that models developed to account for human associative learning may be inaccurate.

The observation of individual differences in non-linear learning supports previous findings presented by Shanks and Darby (1998) and expands upon demonstrations of individual differences in linear learning (Kaufman et al., 2009). The experiments presented here have tested mechanisms accounting for variation in the ability to learn about distinct stimulus configurations.

Kaufman et al (2009) found that ability to learn a linear discrimination was associated with intelligence. Variability in non-linear discrimination learning, however, is unlikely to be accounted for in terms of intelligence or working memory capacity alone. Throughout the experiments presented here working memory capacity was not observed to be associated with ability to solve non-linear discriminations. Most participants were Oxford University undergraduate students and therefore the intelligence of participants may be expected to be relatively homogenous. As such, it is likely that variability in performance occurred in the absence of differences in intelligence. The experiments presented here, however, included relatively limited assessment of working memory capacity and no measure of intelligence. Further research is needed before the role of working memory capacity or intelligence in accounting for variability in non-linear discrimination learning can be ruled out.

In Experiments 3 and 4 participants' tendency to focus on specific details, as opposed to a global configuration, was found to be associated with poor non-linear discrimination learning. This observation relates to previous research where the perceptual properties of stimuli were varied (Melchers et al,. 2008). For instance, when stimuli have varied along separable dimensions, where the individual stimuli are readily discernible when presented in compound, linear patterns of learning, such as summation, are observed. Thus it appears that ability to process separate stimuli, as opposed to more holistic or global representations, promotes a tendency to engage in linear, as opposed to non-linear, learning. This may be the case both when ability to process stimuli changes as the result of external factors, such as the stimuli dimensions varied, or internal factors, such as dispositional tendency or experience.

The observation of a relationship between hierarchical level of processing (i.e., processing specific details or global configurations) and ability to engage in non-linear learning, suggested a framework to account for flexibility in learning. Previous attempts have been made to account for flexibility of learning (Kinder & Lachnit, 2003; Wagner, 2003). These accounts predominantly focus on changes in the ability to perceive similarity between compounds and constituent stimuli. While this may be a valuable approach to considering the effect of variation in stimulus dimensions, it does not seem suitable for accounting for individual differences in human learning.

A novel approach to accounting for flexibility was presented in Chapter 4, focusing on variation in stimulus sampling capacity. This model provides clear parameters for how and when ability to engage in non-linear discrimination learning should change. As such, the extent to which non-linear discrimination learning is expected can be stipulated a-priori, allowing thorough testing of the model. Further research is required to test the validity of this approach.

6.3 NEUROTICISM AND NON-LINEAR DISCRIMINATION LEARNING

Stress is associated with a narrowing of attention (Christianson et al., 1991; Loftus et al., 1987) and states of high emotional arousal are associated with a tendency to process specific details as opposed to attending to the bigger picture (Fredrickson & Branigan, 2005). As neuroticism is associated with chronic distress (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004; Suls & Martin, 2005; Uliaszek et al., 2010), individuals with higher levels of neuroticism may be expected to show a tendency to process specific details and thus show impaired non-linear discrimination learning. This hypothesis was tested in Experiments 1 and 2. Contrary to these hypotheses neuroticism was associated with strong non-linear discrimination learning. The results of these experiments indicate that differences in processes of learning with non-emotional information are associated with neuroticism. As such, this finding expands on previous observations of associations between neuroticism and biases in non-emotional information processing. The results presented here demonstrate that associative learning tasks may be of value in further exploring biases in information processing that may underlie neuroticism and thus risk for mental health problems.

There are various factors that may account for the association between neuroticism and strong non-linear discrimination learning. First neuroticism may not be associated with a tendency towards processing specific details. Secondly, it has been suggested that stress may be associated with enhanced binding of relevant features (Mather & Sutherland, 2011). Therefore it is possible that neuroticism, by virtue of association with chronic stress, may be associated with enhanced ability to bind relevant features. This may facilitate ability to learn about distinct configurations of stimuli, facilitating non-linear learning. Finally, stress is associated with a shift in attention away from peripheral details and towards specific and salient information. It is possible that changes in processes of attention, associated with neuroticism may facilitate such a shift in attention towards salient and relevant details. This may be expected to reduce the perception of similarity between compounds, reducing generalisation between compounds and thus facilitating discrimination learning. Each of these possibilities is discussed in further detail below.

6.4 NEUROTICISM AND THE TENDENCY TO PROCESS SPECIFIC DETAILS

In Experiments 6 and 8, the association between neuroticism and the tendency to process specific details was tested using the Navon task. Neuroticism was not found to be associated with a tendency to respond to specific details faster than global information. Therefore the association between the tendency to process specific details and poor non-linear discrimination learning observed in Experiments 3 and 4 may not have relevance for understanding the relationship between neuroticism and non-linear discrimination learning observed in Experiments 1 and 2.

It should be noted, however, that individuals with high neuroticism scores were no faster than individuals with low neuroticism scores when identifying targets presented at a global level. Thus, the results of Experiments 1 – 4 suggest that strong non-linear learning is associated with both neuroticism and a tendency to process global information as opposed to specific details and that these factors act independently.

The relationship between global information processing and strong non-linear learning, however, was observed only for individuals with low neuroticism scores. Thus the relationship between neuroticism, levels of processing, and non-linear discrimination learning is unlikely to be straightforward. Future research may benefit from using alternative measures of level of processing, such as the Kimchi and Palmer test (1982). Exploration with a broader range of associative learning tasks related to non-linear learning, such as a summation task and biconditional discrimination, may further help isolate the interaction between these factors.

6.5 NEUROTICISM AND ENHANCED BINDING OF RELEVANT FEATURES

High stress or emotional arousal is associated with enhanced binding of relevant information (Mather & Sutherland, 2011). This may facilitate non-linear discrimination learning. However, Experiment 9, testing the association between neuroticism and speed identifying feature conjunctions in a visual search task did not observe neuroticism to be associated with enhanced ability. Further, in the perceptual learning tasks in Experiment 11, configuration pre-exposure was expected to facilitate the process of unitization of the constituent stimuli of a compound. Configuration pre-exposure, however, had no influence on subsequent discrimination learning. These findings suggest that neuroticism may not be associated with enhanced binding of relevant features and as such, enhanced binding of relevant features alone is unlikely to account for strong non-linear discrimination learning.

There were distinct limitations to both of these studies, discussed in Chapters 4 and 5 respectively. There may be an important distinction between ability to identify conjunctions, as tested in the visual search task in Experiment 9, and ability to encode conjunctions for future use. The learning tasks tested ability to acquire associations with combinations of stimuli and as such relied heavily on functions of memory, not tested in the visual search task in Experiment 9.

The time frame used in the visual search task was considerably shorter than that used in the tests of configural learning. Williams and Braker (1999) observed that under time pressure all participants used an elemental response pattern. This led Williams and Braker (1999) to argue that time is required to encode and use configural associations. Therefore under conditions where a rapid response is required, any advantage in encoding conjunctions may be obscured. Further research testing of ability to bind features independent of time constraints may be beneficial. As such, testing the association between neuroticism, paired associated learning tasks (Messbauer & de Jong, 2003; Williams & Pearlberg, 2006; Windfuhr & Snowling, 2001) and performance on the Embedded Figures Test (Witkin et al., 1971) may be informative.

Limitations of the perceptual learning task were discussed in Chapter 5. Despite the limitations of both the visual search task and the perceptual learning task, the absence of any support from these tasks for an association between neuroticism and ability to bind relevant features, suggests caution in considering the role that enhanced binding of relevant features may have played in the association between neuroticism and strong non-linear discrimination learning.

6.6 NEUROTICISM AND SHIFTING ATTENTION AWAY FROM CONTEXT OR PERIPHERAL INFORMATION.

Finally, it is possible to account for strong non-linear discrimination learning in terms of attention shifting away from context information. Generalisation of associative strength between compounds should be facilitated by a shared context. Through the learning tasks reported here, the training stimuli were consistently presented against the same background stimulus. Because all stimuli were presented in the same context, integrating context information into representations should have increased the perceived similarity between compounds, increasing the potential for generalisation of associative strength. Strong generalisation between similar compound stimuli would account for the pattern of learning shown by individuals with low neuroticism scores in Experiments 1 and 2.

One way to account for the strong non-linear learning associated with high levels of neuroticism in Experiments 1 and 2 would be to assume that individuals with high neuroticism scores engaged in less generalisation because they did not incorporate context information into compound representations. This suggestion accords with several other findings. For instance, dysphoria has been postulated to be associated with reduced sensitivity to context information (Msetfi et al., 2005). Further in Experiment 11, individuals with low neuroticism scores showed an improvement in non-linear discrimination learning following feature pre-exposure. This was not observed for individuals with high neuroticism scores. Feature pre-exposure offered the opportunity for latent inhibition to accrue to context information, allowing attention to shift away from redundant context information. The comparative absence of an effect of the feature pre-exposure condition for individuals with high neuroticism scores may be interpreted in one of two ways. It is possible that individuals with high neuroticism scores rapidly ceased to attend to context information and therefore feature pre-exposure provided no advantage. Alternatively, if individuals with high neuroticism scores did not attend to context information, the pre-exposure experience may not have been effective in providing opportunity for latent inhibition to accrue to context information. These two accounts are not incompatible.

While reduced attention to context information looks to be a promising potential explanation for the association between neuroticism and strong non-linear discrimination learning, several limitations must be considered. First, a shift in attention away from context information should be expected to affect linear discrimination learning as well as non-linear discrimination learning. Reducing the perceived similarity between compounds, or between compounds and their constituent stimuli, may be expected to have facilitated learning the linear discrimination in Experiment 1. Neuroticism did not interact with linear discrimination learning.

Secondly, in Experiment 8, global information in the Navon tasks may be seen to act as the context in which local targets were presented. Neuroticism was not associated with any advantage identifying targets presented at the local level when global level information was incongruent, suggesting that neuroticism did not influence ability to ignore context information when identifying local targets. Further, in completing the Navon task in Experiment 8 individuals with high neuroticism were not better able to prioritize goal relevant information, regardless of the hierarchical level at which target information was presented. These findings do not appear to support the contention that neuroticism is associated with a tendency to ignore or shift attention away from context or redundant peripheral information. As such, caution should be adopted when considering whether a tendency to shift attention away from context information accounts for the association between strong non-linear discrimination learning and neuroticism. Further experiments, directly testing whether neuroticism is associated with altered sensitivity to context information may be beneficial.

6.7 SUMMARY

While the experiments presented here may have raised more questions than they have answered, the findings suggest three important points. First, individuals differ in their ability to learn about combinations of stimuli as distinct configurations, differing from their constituent components. Secondly, individual differences in ability to learn non-linear discriminations may relate to the tendency to process specific details as opposed to global configurations and such flexibility may be modelled by considering variation in stimulus sampling capacity. Finally, associative learning tasks may have value in advancing our understanding of the information processing biases underlying neuroticism.

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