Reduced Generalization in Autism:
An Alternative to Weak Central Coherence

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It has long been observed that individuals with autism exhibit peculiar attentional and perceptual abnormalities. For example, individuals with autism frequently notice minor changes in their environments. In one of the earliest studies of autism, Kanner noted the following statement made by the mother of a child with autism: "On one of the bookshelves, we had three pieces in a certain arrangement. When this was changed, he always rearranged it in the old pattern" (Kanner, 1943; 1973, p.9). This sort of behaviour is consistent with many anecdotal and clinical reports that individuals with autism notice features about a situation or event that to others seem small and insignificant. Another example of this exquisite perception of detail has been observed when children with autism tackle jigsaw puzzles – the solution appears to be derived from the shapes of the pieces rather than the printed picture, so that the child with autism, unlike a normal child, could as easily complete a jigsaw puzzle with the picture facedown as when it is faceup (Frith & Hermelin, 1969). This ability to pick out individual features from some larger entity has also been observed using the Embedded Figures Task and the block design subtest of the Wechsler intelligence scales. Several studies have established that both children and adults with autism show superior performance on these tasks compared with normal individual and individuals with learning disabilities, matched for mental age (Shah & Frith, 1983; Shah and Frith, 1993; Jolliffe & Baron-Cohen, 1997).

This set of behaviours can be described as an acute ability to process fine detail, an ability that can surpass that of developmentally normal individuals. Over the past 10 years, the dominant explanation for these behaviours has been the weak central coherence hypothesis (Frith, 1989). In a general form, the hypothesis states that individuals with autism have a deficit in integrating disparate information in order to extract the "gist" of any situation. The hypothesis is flexible enough to allow predictions to be made at many stages of psychological processing – from perception and selective attention through to conception. Because weak central coherence could operate at any one (or all) of these levels, Frith initially thought that this integration deficit might explain both the superior perceptual and attentional abilities of individuals with autism and their deficits in conceptual-semantic domains of analysis, such as the pragmatic use of language and, indeed, the pervasive social deficits (Frith, 1989). However, this view has been abandoned in light of empirical investigations suggesting that weak central coherence and social deficits may be independent of one another (Happé, 1997; Frith & Happé, 1994). As a result, the weak central coherence hypothesis has become regarded as the explanation for the special abilities and savant skills observed in autism, leaving the theory-of-mind hypothesis (e.g. Baron-Cohen, Leslie & Frith, 1985; Tager-Flusberg, chap 9, this volume) and the executive dysfunction hypothesis (see Russell, 1997, and Hughes, this volume) to battle over the explanation of the co-occurrence of the characteristic triad of impairments in autism (Wing & Gould, 1979).

In this chapter, I argue that more recent evidence is highly suggestive of a causal link between the perceptual and attentional abnormalities in individuals with autism and their deficits in social processing. Given this, we should perhaps readopt the parsimonious position that many aspects of autism stem from one underlying deficit. The question then becomes whether this deficit is indeed a weakening of central-coherence mechanisms, or whether weak central coherence "effects" may be better explained by alternative mechanisms. This question is answered, in part, by reviewing some of the studies that have assessed the weak central coherence hypothesis at the level of perception and selective attention. On the whole, the evidence is not in its favour, although the same cannot be said of studies that assess the weak central coherence hypothesis at the level of conception. My argument is that there is an alternative explanation of the perceptual and attentional abnormalities in autism to weak central coherence that pivots on the notion that individuals with autism are unable to draw pieces of information together because of an inability to recognize the similarities between stimuli or situations. However, the challenge is to assess whether this alternative can also explain weak central coherence effects at the conceptual level. I draw on some recent insights concerning perceptual and conceptual processes in developmentally normal individuals (Goldstone & Barsalou, 1998) to offer possible ways in which a reduced ability to process similarity at the perceptual and attentional level of the kind observed in autism can lead to abnormalities at the conceptual level.

Weak Central Coherence and Social Information Processing

Historically, research in autism has attempted to find an explanation that could account for the entire set of autistic symptoms. In fact, two of the most dominant theories, the theory-of-mind deficit (e.g. Baron-Cohen, et al., 1985) and the executive dysfunction theory (see Russell, 1997) focus on finding a single underlying cause for the triad of impairments (Frith, 1989; Wing & Gould, 1979), rather than on the perceptual and attentional profile in autism. What is so exciting about the weak central coherence hypothesis is that it stands alone as a potential explanation of both the triad of impairments and the perceptual and attentional abnormalities. In her original formulation of the hypothesis, Frith (1989) described how the inability to draw together into a meaningful pattern disparate and complex pieces of information typical of a social interaction could easily give rise to a mentalizing deficit. Similarly, she explained that being unable to extract the "gist" from a speech stream would prevent an individual from understanding the "deeper intentional aspects of communication" (Frith, 1989, p.124). She also applied the hypothesis to the presence of repetitive behaviours – automatically elicited behaviours that are normally inhibited by the operation of those central control processes that are responsible for bringing coherence to experience. Thus, in these three areas, weak central coherence will give rise to deficits in behaviour compared with that of nonautistic individuals. On the other hand, where task success lies in being able to ignore gist or meaning in order to focus on details and parts of objects, weak central coherence will give rise to superior performance, such as in the case of the Embedded Figures Task and the block design task. In this way, the weak central coherence hypothesis elegantly captures both the strengths and weaknesses of the autistic disorder.

However, on the basis of studies conducted by Happé (1991; 1997), Frith has abandoned the idea that weak central coherences is the single underlying deficit in autism (Frith & Happé, 1994). Happé (1991; 1997) compared different groups of individuals with autism – individuals who showed no ability to pass theory-of-mind tasks, individuals who passed first-order theory-of-mind tasks, and individuals who passed second-order theory-of-mind tasks – with developmentally normal children on the ability to correctly pronounce homographs embedded within sentence contexts. Her prediction was that if weak central coherence underlies theory-of-mind deficits, then those individuals with autism who were unable to pass theory-of-mind tasks would show a deficit in the homograph task, whereas those who showed good theory-of-mind performance would show a level of performance comparable with that of normal children. Because all of the individuals with autism, regardless of their ability to solve theory-of-mind tasks, showed deficits on the homograph task, Happé (Happé, 1997; 1994) concluded that central coherence and theory-of-mind skills were underpinned by independent mechanisms and that individuals with autism suffered deficits in both.

One possibility, then, is that weak central coherence underlies the perceptual and attentional abnormalities in autism, whereas theory-of-mind deficits and executive dysfunction underlie aspects of the triad of impairments. The question then becomes one of how these three mechanisms are related, a question addressed by others in this volume. However, there is another line of inquiry that raises another possibility. This research suggests, contrary to Frith and Happé's conclusions, that central coherence and theory-of-mind performance are, in fact, causally linked. If this is so, then we return to the possibility that the various aspects of autism may stem from the same underlying psychological mechanism.

Some of this research has been conducted by Baron-Cohen and his colleagues (Baron-Cohen & Hammer, 1997; Baron-Cohen, Joliffe, Mortimore, & Robertson, 1997). Each of these studies compared two populations (for example, female and male adults, of parents of children with Asperger's syndrome and parents of developmentally normal children, or individual with and without autism and those with Asperger's syndrome) on the Embedded Figures Task as the test for central coherence and the "Mind in the Eyes" task as the test for mentalizing. In the Mind in the Eyes task, participants were presented with a pair of photographic images, each displaying the eye region of a face and asked which of the pair indicates a particular mental state, such as "sympathetic" or "concerned" or "playful." In each population of participants, he found an inverse relationship between performance on the Embedded Figures Task and the Mind in the Eyes task, strongly suggesting a link between central coherence and mentalizing skills.

A similar conclusion was drawn by Jarrold, Butler, Cottington, and Kimenez, (2000), who argued that Happé's (1997) study provides no direct evidence against the hypothesis of a causal link between weak central coherence and poor theory-of-mind skills, because those individuals who were able to solve second-order-theory-of-mind skills were likely to have developed this ability later than developmentally normal children. This late development may well have been caused by weak central coherence. Accordingly, Jarrold et al. (2000) examined the relationship between weak central coherence and theory-of-mind performance in individuals with autism on test of mentalizing in the form of a battery of theory-of-mind tasks that required belief inference and the Embedded

Figures Task. Significant inverse correlations between the two were found when verbal mental age and verbal mental age plus chronological age were partialled out.

Evaluating Perceptual Weak Central Coherence

These studies resurrect the potential importance of the weak central coherence hypothesis as an explanation of the major characteristics of autism. Thus, the central issue becomes what are the mechanisms of weak central coherence? Only by addressing this can we discover how weak central coherence explains the various symptoms of autism. The difficulty, however, is that the weak central coherence hypothesis is a rather unformulated notion. Frith's use of the word "central" refers to processes that are marshaled in order to extract the overall meaning from a range of informational inputs (Frith, 1989). If these processes are truly "central", then weak central coherence might be expected to affect many levels of processing, from perception (often referred to as weak central coherence at "lower" levels) to conception (often referred to as weak central coherence at "higher" levels). The problem is knowing what the central processes are. For example, they could be those processes responsible for building a mental model or schema (Johnson-Laird, 1983). Or they could be attentional control processes, which select from a range of input that which is goal-relevant and inhibit that which is not. However, it is not at all clear how deficits in these sorts of processes would give rise to weak central coherence at the level of perception. Perceptual weak central coherence may be more likely the result of abnormal or weakened gestalt processes, responsible for the integration of the component parts of a stimulus into a global whole. And, if this is the case, the word "central" becomes redundant, because gestalt processes are usually thought of as innate principles of perceptual organization.

Most researchers who have tested weak central coherence in autism at the perceptual level have adopted the idea that weak central coherence derives from a deficit in perceptual integration processes, which weakens the ability to perceive a gestalt. Hierarchical stimuli, in which a larger figure such as a letter *h* is composed of a number of other smaller figures, such as the letter *s*, were used in at least four studies (Mottron & Belleville, 1993; Mottron, Burack, Stauder, & Robaey, 1999; Ozonoff, Strayer, McMahon, & Filloux, 1994; Plaisted, Swettenham, & Rees, 1999). In such tasks, the participant is required to respond to either the larger global figure or to the smaller local figures. Typically, (although not always) developmentally normal individuals respond faster and more accurately to the global than to the local level of the stimulus (Navon, 1977). And, contrary to the expectations of the weak central coherence hypothesis, the same has been found for individual with autism. If the weak central coherence hypothesis is interpreted in its strictest sense, as a deficit in the integration of stimulus input resulting in an inability to perceive gestalt wholes, these results can be seen as staunch evidence against it.

Frith probably did not have this in mind, as she states that weak central coherence comes about because individuals with autism cannot see the *need* to draw separate pieces of information (or at the perceptual level, parts of a stimulus or scene) together (Frith, 1989). This implies that individuals with autism should be able to *perceive* a gestalt, but have a tendency to *attend* to the local parts of the stimulus. And, on the whole, these studies primed participants to attend to either the global or the local level prior to a block of trials, by telling them to identify the large (global) letter or the small (local) letter. Thus, according to the idea that individuals with autism do not ordinarily see the need to attend to the global whole, it is not surprising that when they are explicitly informed of the need to attend to the global level, they process the gestalt figure in the normal way. However, we (Plaisted et al., 1999) also included a task that required participants to inspect both the local level and global level of the stimulus on each trial, a procedure that prevented priming attention to one or another level by instruction. Under these conditions, individuals with autism exhibited a weak-central-coherence effect by responding more accurately to the target figure at the local than the global level.

This finding can be seen as consistent with Frith's version of the weak central coherence hypothesis, that in the absence of a drive for global meaning, individuals with autism have a tendency to attend to the local level. However, the important fact is that the weak central coherence theory does not tell us why such as effect should come about – it simply describes the effect. We (Plaisted et al., 1999) suggested that one reason may lie in the relative levels of activity in the two visual channels responsible for high- and low-spatial-frequency processing. The faster and more accurate responding to the global level of a hierarchical stimulus in developmentally normal adults may relate to the relatively higher levels of activity in low-spatial-frequency channels (Badcock, Whitworth, Badcock, & Lovegrove, 1990). When adults are adapted to low–spatial-frequency gratings, preferential global processing reverses to preferential local processing. If this balance is reversed in autism, the local level should be processed prior to the global. Furthermore, the relative levels of activity in these visual channels do not appear to be fixed, but can be modulated by attentional processing, possibly mediated by parietal mechanisms (Robertson & Lamb, 1991). When adults search for a target that is more likely to appear at the local than the global level, they show faster and more accurate performance at the local compared with the global level (Kinchla, Solis-Macias, & Hoffman, 1983). Thus, the level of the stimulus that should be attended to can be primed, and this appears to override, in developmentally normal individuals, any "default" setting of activity levels within the spatial frequency channels. The normal performance of individuals with autism on hierarchical stimulus tasks in which target levels are primed suggests that this is also the case in autism.

A similar analysis could be applied to the finding that individuals with autism do not succumb to all visual illusions. Happé (1996) assessed children with autism on their propensity to succumb to six visual illusions. Although a similar percentage of children with autism and children with learning disabilities matched for mental age succumbed to one of the illusions (the Muller-Lyer), a rather lower percentage of children with autism succumbed to the remaining five (the Ponzo, Kanisza, Tithcner, Hering and Poggendorf illusions). This might be explained by enhanced levels of activity in high-spatial-frequency visual channels, thereby providing sufficiently more information about the local parts of the illusory figures to prevent the illusion that is derived only from low-spatial-frequency information concerning the global level. If global processing operates normally in autism when primed by instruction, then this effect should disappear when children with autism are asked a question about the illusion that refers to the global level. Some consistent evidence is available from a study in progress that is being conducted by Scott, Brosnan, and Wheelwright (submitted). They wondered whether the participants with autism in Happé's study (1996) interpreted the questions asked (e.g., "Are these two lines the same length?" in the Ponzo illusion) in a literal way. They therefore asked their participants two questions about each illusion, one of which referred to the actual form of the stimulus (e.g., "Is there a triangle?" in the case of the Kanisza triangle illusion) and another that referred to the appearance of the stimulus (e.g., "Does it look like there is a triangle?"). They found that individuals with autism can see the actual form of the stimulus and the illusion. The appearance question could therefore prime the individual with autism to attend to the global level of the stimulus, thus overriding otherwise enhanced local processing.

There are very few other convincing demonstrations of perceptual weak central coherence. Jarrold and Russell (1997) attempted to test the hypothesis by asking children to count dot stimuli, which were presented either in canonical form (i.e., like the arrangement of dots on dice) or in a distributed form, where the dots appeared randomly arranged with several other distracters (small squares). They suggested that, according to the weak central coherence hypothesis, children with autism should show no benefit for dots arranged canonically, whereas developmentally normal children and children with learning disabilities would find counting easier in the canonical condition than in the distributed condition. Although there were no differences between groups for counting in the two conditions when there were only three and four dots, the two groups without autism showed more benefit from having stimuli presented in canonical form that in distributed form when there were five or six dots to count. However, Jarrold and Russel (1997) note that some children within the group with autism showed as much benefit from canonical presentations as the other groups, and the proportion of these "global" counters did not differ significantly from the proportion of global counters in the group of children with learning disabilities.

In one study that is frequently cited in favor of perceptual weak central coherence, Shah and Frith (1993) compared developmentally normal individuals and individuals with autism on a "pre-segmented" from of the block-design task They argued that if individuals with autism fail to perceive the overall gestalt of the pattern, they should, unlike developmentally normal individuals and individuals with learning disabilities, show no benefit from the presentation of the pattern to be copied in a segmented form compared with their performance when it is presented as a complete form. Shah and Frith (1993) also compared groups on patterns presented rotated versus nonrotated and patterns with and without oblique lines. They found an interaction between groups only in the segmented versus nonsegmented condition. Thus, nonautistic groups appeared to benefit no more than individuals with autism by nonroated and non-oblique line patterns but were facilitated by segmentation.

There are, however, reasons to be cautious about this result. When separate analyses were conducted on the data, Shah and Frith (1993) found that the interaction between the older normal and high-IQ persons with autism was not statistically significant at the 0.05 probability level. One way of salvaging the weak central coherence hypothesis in the light of this nonsignificant result might be to say that if the block-design task marshals the same processes as the Embedded Figures Task, then, given that performance on the Embedded Figures Task improves with age, so may performance on the block-design-task. Thus, by the age of 16 years, developmentally normal individuals may perform to the level of individuals with autism on both segmented and unsegmented forms of the task. However, the weak central coherence hypothesis fares less well from this explanation for the comparison between younger and low-IQ persons with autism, which yielded a significant interaction. If developmentally normal individuals' performance improves with age, then superior performance would be expected from a group of 18-year–old individuals with autism compared to 10-year-old developmentally normal children, regardless of the difference between groups in diagnosis. But why, then did the older individuals with autism show superior performance compared with the other groups only on the unsegmented form? This brings us to the final problem with the data from this study. In both groups of individuals with autism, there were improvements in performance when patterns were presented in segmented form. This strongly suggests that segmentation facilitated all groups, regardless of diagnosis. Although these improvements in the groups with autism were presumably nonsignificant (simple effects were unfortunately not reported), this is some indication that performance in the groups with autism was at ceiling in the segmented version. Thus, if the patterns had been more difficult, individuals with autism may have shown superior performance on both the unsegmented and segmented patterns compared with the other groups, a result that would require some other explanation than weak central coherence.

The evaluation of the weak central coherence hypothesis so far may seem overly harsh. After all, those studies that ostensibly provide evidence against the weak central coherence hypothesis do so by presenting nonsignificant differences between groups with and without autism (Mottron & Breville, 1993; Ozonoff et al., 1994; Plaisted et al., 1999) and null results can be argued either way. The argument against the weak central coherence hypothesis might seem more compelling if a group with autism performed on a task in the opposite way to that predicted by weak central coherence. Such a result was found when performance on conjunctive visual search tasks was compared between children with autism and developmentally normal children (Plaisted, O'Riordan, & Baron-Cohen, 1998a). These tasks require participants to search for a target that shares features with two or more simultaneously presented sets of distracters, such as a green X target among green T and red X distracters. Because the detection of this target among such distracters requires integration of the colour feature green and the shape feature X, the weak central coherence hypothesis predicts that children with autism should perform significantly worse compared with developmentally normal children. In direct contradiction, we found that children with autism were significantly faster. This result is hardly amenable to the idea that priming a gestalt target by instruction (the children were told to look for a green X), boosts the otherwise weak central coherence processes, because this merely predicts that the performance of the two groups would not differ. The finding of superior performance in the opposite direction to that predicted by weak central coherence requires an entirely different explanation. The explanation I shall offer later not only accounts for this superior performance, but also suggests an alternative explanation for the other demonstrations of superior performance in perceptual-attentional tasks that have generally been regarded as weak central coherence effects.

Evaluating conceptual weak central coherence

In contrast to perceptual weak central coherence, conceptual weak central coherence has received relatively little direct empirical testing. However, there are phenomena within the literature that are certainly consistent with the idea that children with autism are less able to extract meaning from a given array of information. For example, Hermelin and O'Connor (1967) found that children with autism were less able than developmentally delayed children to chunk items according to categories from a word sequence that exceeded memory span. Similarly, Tager-Flusberg (1991) found that children with autism, unlike developmentally normal and learning disabled children, were not facilitated in immediate free recall by semantic similarity in a list of nouns.

The better known studies that are cited in support of conceptual weak central coherence have assessed the ability of individuals with autism to correctly pronounce homographs within the context of sentences. Frith & Snowling (1983) found that children with autism read fewer homographs correctly in context compared with developmentally normal and dyslexic children. This is consistent with the idea that individuals with autism are less able to extract the "gist", which might normally determine the correct pronunciation. Unfortunately, this study did not determine whether or not this effect is specific to autism, since the developmentally normal children, although significantly better at homograph pronunciation than children with autism, were significantly poorer than the children with dyslexia, raising the possibility that these group differences emerged because of differences in general mental functioning. Although IQ scores were not reported for the developmentally normal children, it is possible that they were of lower average IQ than the group of children with dyslexia (the upper IQ limit in that group was over two standard deviations above the mean) and of higher average IQ than the children with autism (the lower IQ limit in the group of children with autism was over three standard deviations below the mean).

The specificity of the homograph pronunciation effect to autism was further challenged by Snowling and Frith (1986), who assessed children with autism, children with learning disabilities and developmentally normal children on the homograph task. Half of each group of children were of high verbal ability and the other half were of low verbal ability. Regardless of diagnosis, children of high verbal ability scored higher than children of low verbal ability. Furthermore, there were no differences in performance between the three groups of children of low verbal ability. These findings appear to confirm the impression given by

Frith and Snowling's data (1983) that using context to disambiguate homograph pronunciation has less to do with weak central coherence in autism than with low general mental functioning.

Two further studies need to be taken into account before accepting this conclusion. In Happé's (1997) study (discussed previously), the group of individuals with autism who passed second-order-theroy-of-mind tasks had a full-scale IQ of less than one standard deviation below the mean and, unlike the developmentally normal group (whose IQ data were not reported), showed no facilitation in performance when the homograph was presented toward the end of the sentence – i.e., after the context had been supplied. And, in a rigorously controlled study with respect to IQ matching, Joliffe (1997) compared high-functioning adults with autism and developmentally normal adults, matched on full-scale IQ, on the homograph task, and again found facilitation in the normal group when the homograph was presented after the sentence context and no facilitation in the group with autism.

It is not clear how the results of these later studies can be reconciled with Snowling and Frith's (1986) data, which showed that homograph disambiguation by sentence context is related to general mental functioning. The most useful approach is to adopt the stance that when nonautistic individuals with low IQ produce patterns of performance that are similar to those of individuals with autism, they may do so for entirely different reasons. Thus, when studies reveal null results between these two groups, it is not sufficient to conclude that performance is determined only by nonspecific low mental functioning. What is required in these cases is further testing to decide the case one way or another.

Enhanced discrimination and reduced generalization in autism

If, as I have tried to argue, the evidence for weak central coherence at the level of perception is not in its favour, it makes sense to consider alternative explanations for the kinds of perceptual and attentional abnormalities observed in the behaviours of individuals with autism and their superior performance on tasks like embedded figures. The alternative that I have been considering is that many of the attentional and perceptual abnormalities in autism are phenomena of reduced generalization, or a reduced processing of the similarities that hold between stimuli and between situations. Specifically, I have drawn from elemental theories of generalization, which state that one stimulus will be responded to in a similar way to another if they share sufficient features or elements in common (e.g., Estes, 1950; Pearce, 1987; Thompson, 1965). If they share few features in common, they will be regarded as different stimuli. And, if individuals with autism process similarities between stimuli and situations poorly compared with normal individuals, then they will tend to view even similar stimuli as quite different.

In order to see how this suggestion relates to the performance of individuals with autism on the Embedded Figures Task, it is useful to draw an analogy between this task and a camouflaged detection task. When, for example, a moth is camouflaged against a piece of bark, it is very difficult to detect because many of its features are precisely those of the bark background. Discriminating the moth from its background therefore requires processing those features that are unique to the moth and not shared in common with the bark (Plaisted & Mackintosh, 1995; Plaisted, 1997). Similarly, in the Embedded Figures Task, the target contains some features or elements in common with the overall picture and some unique features that define it. Detection of the target will therefore be enhanced if those unique features are processed well and those features held in common with features contained in the rest of the picture are processed poorly. In the case of the block-design task, again the final solution will be assisted if an individual is able to process well those features that uniquely define the required block face and to ignore those features that are held in common with other faces that may be required for another part of the design.

Acute processing of unique features hinders rather than helps in other situations – such as when trying to transfer learning from one situation to another – especially when the two situations share few common features. Poor transfer, or generalization, is often observed in autism (e.g. Swettenham, 1996; Ozonoff & Miller, 1995). Any simple elemental model of generalization predicts that successful transfer under these conditions will occur if those few features that are held in common between the two situations are processed rather than those features unique to each stimulus and that transfer will be hindered if those common features are processed poorly.

The hypothesis that individuals with autism process features unique to a situation or stimulus relatively well and features held in common between situations or stimuli rather poorly, makes two complimentary predictions. First, individuals with autism should show superior performance on a difficult discrimination task – i.e., one where stimuli to be discriminated hold many elements in common and each possesses very few unique elements. Second, individuals with autism should show inferior performance on a task that requires categorization of two sets of stimuli.

Support for the first prediction was found in a perceptual-learning task (Plaisted, O'Riordan, & Baron-Cohen, 1998b). Perceptual learning describes the phenomenon whereby two very similar stimuli, which at first appear indistinguishable, become distinguishable following a period of simple exposure. As a result of exposure to the stimuli, elements held in common (and which initially prevent discrimination) become less salient and the unique elements of each stimulus become relatively more salient (see McLaren, Kaye, & Mackintosh, 1989, for a model of the mechanisms underlying perceptual learning). If, however, individuals with autism process the unique elements of stimuli well and the common elements poorly, they should not require exposure to the stimuli in order to discriminate them. In our experiment (Plaisted et al., 1998b), we compared high functioning adults with autism and normal adults on their ability to perform two discriminations. One discrimination involved two highly similar stimuli that had been preexposed, the other involved two entirely novel similar stimuli. The group of normal adults showed the classic perceptual learning effect; they solved the discrimination between the two preexposed stimuli significantly better than the discrimination between the two novel, non-preexposed stimuli. The group of adults with autism, however, performed significantly better on the novel discrimination problem compared with the normal adults. They also did not show the perceptual learning effect: they performed as well on the discrimination involving novel stimuli as on the discrimination involving the preexposed stimuli. This is consistent with the idea that unique features are processed well and common features processed poorly by individuals with autism and relates to the nature of the stimuli employed in this task. The stimuli that were preexposed contained only some features in common to those presented during the test phase. Furthermore, these features were also held in common between the two stimuli in the test discrimination, and were therefore the features to be ignored when trying to solve the discrimination. Thus, benefiting from preexposure in this procedure required participants to process those features of the test stimuli that were held in common with the preexposure stimuli as familiar. This would therefore facilitate the test discrimination. However, if individual with autism do not process common features well – whether those held between two concurrently experienced stimuli or those held between the current experience and prior experience - such facilitation would not occur.

Support for the second prediction, that individuals with autism should show a deficit in categorization, was found using a prototype abstraction task (Plaisted, O'Riordan, Aitken, & Killcross, submitted). When typical adults are first trained to categorize two sets of exemplars, they are subsequently able to categorize the prototype of each set more accurately than other nonprototypical exemplars, even though they have never experience the prototype before. Any explanation of this prototype effect appeals to a mechanism of estimating the similarity between exemplars. Because the prototype is the central tendency of the set of training exemplars, its similarity to the trained set will be higher than that of any other novel but nonprototypical exemplar and it will therefore be categorized more accurately. Categorization and prototype abstraction are, therefore, phenomena of generalization between the common features of a set of exemplars. According to the reduced generalization hypothesis, individual with autism should show a deficit in category learning in the initial categorization phase of a prototype experiment and a reduced prototype effect in comparison to normal subjects. Both predictions were supported.

The hypothesis also provides an explanation of their superior performance on the aforementioned conjunctive visual search task (Plaisted, et al., 1998a). The conjunctive visual search task is difficult for developmentally normal individuals precisely because there is high similarity between the target and the distracters (Duncan & Humphries, 1989). However, if this similarity is processed less well by individual with autism, the target effectively "pops out" from the other items in the array. We tested this further by administering to high-functioning children with autism and developmentally normal children conjunctive search tasks that varied target-distracter similarity. Increasing the similarity between targets and distracters impeded the performance of the developmentally normal children, but not the children with autism (O'Riordan & Plaisted, in press).

Thus, the hypothesis of reduced generalization appears to provide an alternative account for the kinds of phenomena often descried as perceptual weak central coherence and has generated novel predictions that are supported in a variety of tasks. One remaining important question is how well this hypothesis can account for the phenomena described as conceptual weak central coherence. My argument is that it is often the unique features of a situation that are the least important when trying to make sense of an experience - understanding is much more easily derived from assimilating current experience with what one already knows. But assimilation can be successful only if one recognizes that there are features of the current situation that have been encountered in previous situations – i.e., are held in common with those past experiences. Any reduction in the processing of common features will cause a deficit in this process of bringing prior experience to bear on new experiences. In effect, this amounts to a deficit in extracting the meaning or gist of a current experience. Furthermore, the proposal that individuals with autism process unique features somewhat better than developmentally normal individual can account for why individuals with autism notice features that seem obscure or irrelevant – these are likely to be the unique features, which are generally rejected by the normal individual as irrelevant because they are unable to contribute to the process of assimilation.

Possible Mechanisms Underlying Reduced Generalization

The hypothesis that individuals with autism process unique features well and common features poorly compared with nonautistic individuals is based on theories that state that any stimulus is represented as a set of elements (e.g., Esters, 1950; McLaren et al., 1989). These elemental theories of stimulus representation provide a foundation from which speculations may be made about why individuals with autism show reduced generalization between stimuli that hold features in common. These theories assume that generalization from one stimulus to another normally occurs to the degree to which the elements of one stimulus are able to excite the elements of the other, by *associative excitation.* Theories differ with respect to what causes that associative excitation. For example, the activation of one stimulus representation may excite another by virtue of the representation of an outcome with which both stimuli have been equally paired in the past. Such an effect is known as acquired equivalence (Hall, 1992). Alternatively, associations could be formed between each and every elements of one stimulus during exposure to that stimulus (so that the individual need only sample a small proportion of the total set in order for the full representation to be activated). The consequence of that process is generalization to another stimulus by the virtue of the elements shared in common; that is, the activated common elements of the first stimulus will retrieve, by associative excitation, not only its own remaining set of elements, but also the remaining elements of the second stimulus that share the activated common elements (McLaren et al., 1989).

But any such theory needs also to account for the perceptual learning phenomenon – the reduction of generalization over time between stimuli that share elements in common. Any reduction in generalization effectively comes down to a reduction in the salience of the elements held in common. There are two learning mechanisms known to reduce salience: latent inhibition and habituation. Latent inhibition is the phenomena whereby mere exposure to a stimulus retards the propensity of that stimulus to enter into association with any other stimulus at a later occasion. McLaren et al. (1989) proposed that latent inhibition is the primary process that reduces generalization between two stimuli to preclude perceptual learning (i.e., enhanced discrimination). They assume that during exposure to the two stimuli, each element of each stimulus gradually becomes latently inhibited. However, because the elements common to both stimuli, are, in effect, presented twice as often as the unique elements, they will become twice as latently inhibited as the unique elements. Thus, by the end of preexposure, the common elements are relatively less salient than the unique elements, and therefore the unique elements are better able to enter into new associations with the discriminative response. This leads to better discrimination, or reduced generalization. Is it possible, then, that mechanisms of latent inhibition operate with greater efficiency in autism? Possibly – but this would not explain our finding that individuals with autism show enhanced discrimination between highly similar stimuli. Enhanced latent inhibition would affect common and unique elements equally, and if the unique elements were very much less salient for the individual with autism compared with other individuals, one might even expect the opposite result.

Differences in the processes of habituation, however, could well account for the reduced generalization we have observed in autism. Killcross and Hall (in preparation) propose that perceptual learning (or reduced generalization) in any individual is the result of differential habituation (rather than latent inhibition) of common and unique elements. *Habituation* is a nonassociative learning process in which repeatedly presented stimuli lose their capacity to elicit a response. Like McLaren et al. (1989), Killcross and Hall propose that common elements will lose salience at faster rate than unique elements because they are presented twice as often as unique elements, but through habituation rather than latent inhibition. However, they additionally propose that in the case of similar stimuli, common elements will, at the outset, be more salient per se than unique elements. They will therefore receive greater processing of the sort that leads to habituation than will unique elements. Thus, during preexposure, the common elements will be more than twice reduced in salience compared with the unique elements. This possibility simultaneously predicts our empirical results of more rapid discrimination performance and poorer prototype abstraction in categorisation tasks.

This analysis of reduced generalization is based on learning mechanisms that may reduce associative excitation between encoded elements of two or more stimuli. However, a reduction in associative excitation could be the outcome of differences in even more fundamental processes, such as perception. For example, Gustafsson (1997) proposed that the excellent discrimination skills that have been observed among persons with autism could be caused by excessive lateral inhibition between neurons. This, he argues, would impact the development of cortical maps, which respond to a range of stimuli that share certain common properties (Kohonen, 1984). Furthermore, since lateral inhibition is a general mechanism that operates throughout the central nervous system, excessive lateral inhibition could affect processing at any level, including perception. This kind of suggestion raises the possibility that perception in autism is altered such that stimuli are perceived with greater acuity and thus with greater differentiation, allowing small and seemingly irrelevant stimuli to be perceived as important and salient features.

This might account not only for the superior performance of individuals with autism on the Embedded Figures Task but also other effects such as enhanced local processing on variants of the Navon task that do not prime participants to attend to the global level. Kimchi (1992) argues that the local parts of a hierarchical stimulus are only perceived when the elements are large and few in number. When they are small and densely spaced, they are perceived instead simply as the texture of the overall figure (Kimchi & Palmer, 1982). Perceiving local parts of a whole therefore depends on the extent to which the elements are perceived as differentiated. The suggestion that perception in autism operates to enhance the differentiation of perceptual elements, therefore, predicts that individuals with autism will perceive the elements as local parts in hierarchical stimuli in which normal individuals perceive elements as texture. But why should this lead to enhanced local processing in autism? According to Kimchi (1992), the dominance of global processing over local processing in developmentally normal individuals occurs only when the elements are perceived as texture. However, when the elements are larger and more sparse, developmentally normal individuals show dominance of local processing (Kinchla & Wolfe, 1979; McLean, 1979). Making elements larger and more sparse effectively increases the differentiation between them, so that they are perceived as forms rather than simply as texture (Julesz, 1981). Thus, if the elements of a particular hierarchical stimulus are more greatly differentiated for an individual with autism than for a developmentally normal individual, they may show enhanced local processing compared with that of an individual without autism.

Conception and Categorisation in Autism

The proposal that perception operates differently in autism to allow for finer registration of the available stimuli has important implications for concept formation and category structure in autism and for whether individuals with autism can or cannot categorize. Frith (1989) argued from the weak central coherence hypothesis that individuals with autism have the capacity to categorize, but may not see the need to. Although children with autism do not categorize as well as developmentally normal children, they rarely show deficits compared with mentally handicapped children matched for mental age (e.g., Tager-Flusberg, 1985; Ungerer & Sigman, 1987). I argued elsewhere, however, (Plaisted, 2000) that the capacity of children with autism to form categories is rarely assessed; more often, children's preexisting knowledge of concepts such as vegetables, furniture, or vehicles is the focus of study. Furthermore, researchers typically use sorting or matching-to-sample procedures, which assess simple simultaneous matching processes rather than categorization processes. In one exception, Klinger and Dawson (1995) compared typically developing children, children with learning disabilities, and children with autism on a prototype abstraction task. They found that the performance of children with autism was no worse than that of children with learning disabilities, although they showed poor prototype abstraction compared with typically developing children. However, our finding of high-functioning adults with no associated mental handicap who show a deficit in prototype abstraction (Plaisted et al., submitted) strongly suggests that deficits in categorisation in autism arise for different reasons than the deficits seen in individuals with learning disabilities. One strong candidate is a difference in perception that leads to poor processing of elements or features held in common among stimuli. I suggest that this impinges on all levels of psychological processing.

The most likely response to this is that such differences in perceptual processing would lead only to a deficit in categorisation tasks based on perceptual similarity. Such an objection is based on the long-held and traditional view that there is dissociation between perceptual similarity on the one hand and abstract, rule-based classification on the other. This traditional view holds that cognitive processes operate entirely independently of perpetual processes and that concepts are formed on the basis of either perceptual similarities or amodal symbols.

More recent views have vigorously challenged this dissociation between perception and abstract conception (Goldstone & Barsalou, 1998; Barsalou & Prinz, 1997; Mackintosh, 2000). In their article, Goldstone and Barsalou (1998) mount a persuasive case that conceptual processing is dependent on and derives from perception, not only with respect to perpetual similarity but also to abstract rules. More specifically, they argue that "mechanisms that represent shape, colour and location in perception, also represent shape, colour and location in concepts" (p. 232). In support of their argument, they note the following findings: that categorisation according to an abstract rule is preceded by categorizing exemplars according to perceptual similarity (Allen & Brooks, 1991); that many symbolic concepts derive from perceptual representations (Stigler, 1984; Barwise & Etchemendy, 1991); and that individuals perceptually stimulate the referents of concepts (Wu, 1995; Solomon, 1997). They also highlight the link between perceptually and conceptually based selective attention processes. For example, negative priming (in which a target stimulus on a second trial is responded to more slowly if it had previously occupied the role of an irrelevant distracter on the first trial) is observed using both physically identical stimuli and semantically identical stimuli (Tipper, 1985). Goldstone and Barsalou (1998) pointed out that such studies reveal that perceptually and conceptually based conception share processes of selective attention and inhibition.

If conception, or abstract thought, derives from perception, and perception is different in individuals with autism in the ways I suggest, then it follows that the structure and content of concepts will be quite different in autism. Specifically, the idea that perception in autism enhances the discriminability of stimuli predicts that category boundaries will be sharper and category content much narrower in autism than in typically developing individuals. Furthermore, these qualities of concepts will serve to restrict further development and enrichment of categories and concepts. If categories have sharper boundaries, then it is less likely that novel unusual exemplars (i.e., those that might lie at the category boundary for the developmentally normal individual) will be recognized and encoded as part of an existing category. Such exemplars might therefore be considered meaningless and ignored as a consequence. It is clear what this might mean to understanding emotional expression: It is well known that emotional expressions undergo categorisation during early infancy (e.g., Kestenbaum & Nelson, 1990). However, the child with autism might be expected to encode a highly restricted set of expressions within an emotion concept compared with what a typically developing child might encode and thus ignore, or be unable to understand, an unusual facial configuration as an exemplar of a particular emotion. It is also clear how this might relate to the fact that individuals with autism develop highly restricted interests. These interests tend to be characterized by very specific exemplars, so that a child with autism might be fascinated by a certain make of car, but entirely uninterested in other makes, let alone other forms of transport. Young typically developing children similarly become fascinated with particular categories of stimuli. However, unlike the child with autism, these categories broaden so that one interest leads onto another.

Narrower concepts and sharper category boundaries also have important implications for *semantic processing*, or extracting meaning, because these qualities would reduce the likelihood of activation by associative excitation of concepts that could be brought to bear on making sense of the current array of stimuli. Indeed, a reduction in associative excitation could account for conceptual weak central coherence effects, such as performance on the homograph task. According to several theories of word recognition, an initial lexical-access stage involves the activation of several meanings of the fixated word and the appropriate meaning is subsequently selected given the context provided by the sentence (Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman & Bienkowski, 1982; Rayner & Frazier, 1989). However, in autism, reduced associative excitation predicts that fewer meanings may be initially activated, resulting in an impoverished input on which selection processes can operate.

There are other implications of a reduction in associative excitation as a result of narrower concepts and sharper category boundaries. For example, associative excitation is at the heart of generativity. It is a common experience that one thought sparks or generates another and, in reflecting on a thought sequence, one can recognize the features or elements of one thought that give rise to the next and so on. But a reduction in associative excitation, as a result of the kinds of processes I have outlined, would lead to generativity deficits, deficits that are well documented in autism (Jarrold, Boucher, & Smith, 1996).

Finally, I should consider how this analysis might be brought to bear on social information processing in autism. It is a popular view that the social world is enormously complex and highly variable. No doubt this is true – but it would be extreme to propose that there are no regularities that occur across social situations. Development of social cognition could therefore be conceived (at least in part) as the abstraction of widely applicable social rules by generalization across these regularities, and effective social behaviours in any particular situation can be seen as the utilization of the relevant social rules. And what determines and activates the relevant set of rules, of course, are those features of the current social situation that have been reliably present in previous similar social situations. But a deficit in the ability to process those common features, as observed in our experiments with individuals with autism, will result in a deficit in the abstraction of social rules, and the consequent reduction in associative excitation will result in poor social interaction and social understanding in any one situation. It may therefore be that the superior processing of those features that are unique to a situation and the poor processing of those features held in common among situations substantially contribute to the profound deficits in the social domain observed among persons with autism.

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