Cognition 109 (2008) 157–162

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Brief article

Lexical effects on speech perception in individuals with "autistic" traits

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ARTICLE INFO

Article history:
Received 20 May 2008
Revised 17 July 2008
Accepted 18 July 2008

Keywords:
Autism
Speech perception
Identification shift
VOT
Autism-Spectrum Quotient

ABSTRACT

It has been claimed that Autism Spectrum Disorder (ASD) is characterized by a limited ability to process perceptual stimuli in reference to the contextual information of the percept. Such a connection between a nonholistic processing style and behavioral traits associated with ASD is thought to exist also within the neurotypical population albeit in a more subtle way. We examined this hypothesis with respect to auditory speech perception, by testing whether the extent to which phonetic categorization shifts to make the percept a known word (i.e., the 'Ganong effect') is weakened as a function of autistic traits in neurotypicals. Fifty-five university students were given the Autism-Spectrum Quotient (AQ) and a segment identification test using two word-to-nonword Voice Onset Time (VOT) continua (*kiss-giss* and *gift-kift*). A significant negative correlation was found between the total AQ score and the identification shift that occurred between the continua. The AQ score did not correlate with scores on separately administered VOT discrimination, auditory lexical decision, or verbal IQ, thus ruling out enhanced auditory sensitivity, slower lexical access or verbal intelligence as explanations of the AQ-related shift in phonetic categorization.

1. Introduction

Autism Spectrum Disorder (ASD) represents a spectrum of disorders characterized by a triad of impairments in social, communicative, and imaginative activities (Wing, 1981). Cognitive models have attempted to explain aspects of the profile associated with ASD. One theory, Weak Central Coherence (WCC) suggests that those with ASD have a style of processing which results in a weakening of the ability to integrate information into a meaningful whole or a 'gestalt', while the ability to focus on the detail is preserved or even enhanced (Happé & Frith, 2006). WCC receives empirical support from a number of characteristics associated with ASD, including resilience to visual illusions induced by embedding (Happé, 1996), facility in visual segmentation (Shah & Frith, 1993) and high incidence of absolute pitch (Heaton, Hermelin, & Pring, 1998). Similar tendencies have been reported in linguistic tasks, where autistic individuals tend not to employ semantic context to disambiguate homographs (Happé, 1997) or sentences (Jolliffe & Baron-Cohen, 1999).

Findings such as these suggest that people with ASD may also display dissociation between detail/local vs. contextual/global information in lower levels of linguistic processing such as speech perception. As the existing evidence indicates that the effects are most likely to occur in areas where semantic information offers a backdrop for processing, we have turned our attention to the influence of lexical knowledge on phonetic categorization.

Auditory speech perception is known to be affected by the lexical status of a phonetic sequence. In a seminal study, Ganong (1980) demonstrated that listeners shift their segment identification along a Voice Onset Time (VOT) dimension to make the percept a real word rather than a nonword (e.g., *kiss* vs. *giss*). This process can be seen as a form of central coherence in that the lexical context of the sound influences the perception of the auditory stimulus top-down. We thus predict that this effect will be

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doi:10.1016/j.cognition.2008.07.010

attenuated in people with autistic traits. In this study, we elected to test this hypothesis within neurotypical individuals, taking their Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) as a predictor variable. The motivation behind our decision to test neurotypicals was threefold. First, WCC hypothesizes that the balance between local and global (bottom-up vs. top-down) processing is a matter of style rather than deficit (Happé & Frith, 2006). In other words, the extent to which individuals focus on local information at the expense of global integration forms a single continuum that includes neurotypicals as well as those who display ASD (Baron-Cohen et al., 2001). Second, impairments in language are one of the core features of ASD (American Psychiatric Association, 1994), which potentially affects their lexical knowledge and access. Our aim was to examine how a similar level of lexical information can affect phonetic processing to different degrees depending on the individual's autistic traits. We therefore reasoned that it would be informative to study a homogeneous sample of neurotypicals, whose lexical knowledge and access can be assumed to be less variable than that of the ASD population. In addition, by assessing whether certain social, communicative, and imaginative traits in neurotypical individuals are associated with phonetic perception, we would be able to examine the extent to which individual differences in personality have any bearing on a basic cognitive process such as auditory speech perception. If a relationship is found, it will have significant implications for the intensely debated domain-specificity of speech processing as a cognitively distinct module (e.g., Kluender, 1994; Liberman & Mattingly, 1985; Trout, 2001).

In order to scrutinize the hypothesis that the phonetic processing of individuals with high AQ is less affected by lexical information due to weak central coherence, we also examined other ways in which attenuated lexical effects in phonetic processing may be related to high AQ. First, it is possible that individuals with high AQ possess high auditory sensitivity or enhanced perceptual processing (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006), which may lead to robust phonetic discrimination abilities that are immune to lexical effects. There is currently no conclusive evidence in support of such auditory sensitivity in autism (Rogers & Ozonoff, 2005). However, there is some evidence suggesting that individuals with autism show enhanced discrimination of pure tones (Bonnel et al., 2003). Given our still poor understanding of the nature of sensory features in autism, we opted to examine this possibility by testing our participants' ability to discriminate the relevant acoustic differences.

Second, it may be the case that high AQ is connected to slower lexical access, as some individuals with ASD are known to have language impairments. This in turn can reduce the effects of the lexical status of the phonetic stimuli. To check against the possibility that AQ is confounded with lexical access, we also administered a lexical decision task.

In addition, there is the possibility that the degree of lexical involvement in a perception task may be influenced by the listeners' verbal intelligence. This could result in a correlation between AQ and lexical effects, since autistic individuals have been associated with an IQ profile with a relatively low score on verbal IQ in comparison to performance IQ (Rumsey, 1992; Yirmiya & Sigman, 1991). Therefore, we have also attempted to examine the contribution of verbal IQ, in this case measured by the Mill Hill Vocabulary Scale (Raven, Court, & Raven, 1988).

In sum, the main purpose of this study was to test the hypothesis that individuals with high AQs tend not to be influenced by lexical contexts in their phonetic speech perception. A secondary purpose of the study was to examine the potential contributions of factors that are extraneous to the integration of lexical knowledge and phonetic information.

2. Methods

2.1. Participants and general procedure

Fifty-five undergraduate students at a British university, all native speakers of English, took part in the study as part of a psychology course. Their age range was 18–33, with a mean of 21.4 ($SD = 3.2$). Thirty-seven of them were female and 18 were male. All participants were given five tasks: an identification task with word-to-nonword continua, an ABX discrimination task with a nonword continuum, a lexical decision task, the AQ test, and the Mill Hill Vocabulary Scale test.

2.2. Word-nonword continuum identification

2.2.1. Materials

Two word-to-nonword VOT continua were produced by digitally cross-splicing naturally spoken tokens of *gift* and *kift*, and *kiss* and *giss*, respectively. The original tokens were read by a male British received pronunciation (RP) speaker, and recorded at a sampling rate of 48 kHz. The initial proportions of *kift* and *gift* were replaced by those of *kiss* and *giss*, respectively, such that the endpoint pairs were acoustically identical up to 100 ms after the onset. These tokens were then cross-spliced to produce two equal-step 7-point continua ranging from *gift* to *kift* and from *giss* to *kiss*. The VOTs at endpoints were 8.77 ms and 65.60 ms, respectively, and each step was approximately 9.46 ms with some minor adjustments made in order to enable splicing at zero-crossings. The stimuli were down-sampled to 11 kHz before they were mounted on a stimulus presentation program (E-Prime).

2.2.2. Procedure

The participants listened to the recorded stimuli played on a computer over headphones and pushed the *g* or *k* key to indicate their impression of the first segment of each stimulus. The session consisted of two blocks of trials. In each block, all 14 stimuli were presented 4 times in a random order. Each stimulus was therefore played 8 times (4 times $\times$ 2 blocks).

2.3. Nonword ABX discrimination

2.3.1. Materials

A 9-step continuum was created using a Klatt synthesizer (SenSyn version 1.1). Each utterance was 250 ms long and had the same rise-fall F_0 contour. Formant transition patterns were set to make the stimuli sound like utterances ranging from /gɪ/ to /kɪ/. The base stimuli were generated at 16-bit resolution and 11 kHz sampling rate. ABX stimuli were created by concatenating two base stimuli 20 ms apart (e.g., 0 and 20 ms) with an inter-stimulus interval of 1 s.

2.3.2. Procedure

The participants listened to the ABX stimuli played on a computer over headphones and pushed the 1 or 2 key to indicate whether the third sample was identical to the first or the second sample. The session consisted of two blocks of trials. In each block, all four permutations (i.e., ABA, ABB, BAA, and BAB) of the 8 sets of ABX stimuli were presented once in a random order. Each VOT step was therefore tested 8 times (4 times $\times$ 2 blocks).

2.4. Auditory lexical decision

2.4.1. Materials

The stimuli were 48 recorded tokens of real words and nonwords read by a male RP speaker. Half the tokens were experimental items designed to be similar to the word-nonword pairs in the identification task in that they contrasted in voicing of the initial consonant. They were all monosyllabic words with an initial stop onset, with the real word members matched for frequency with *gift* and *kiss* based on lemma counts in the British National Corpus (British National Corpus Consortium, 2001). The place of articulation ([p/b], [t/d], [k/g]) and the voice/voiceless direction with respect to the word-nonword status were controlled for. All experimental items are given in Table 1. The other 24 tokens were fillers, half of which were real words (e.g., *lift*, *cheese*, *brown*) and the other half nonwords (e.g., *ninch*, *rop*, *twale*).

2.4.2. Procedure

The participants listened to the recordings of the 48 lexical items played on a computer over headphones and pressed the *y* ('yes') or *n* ('no') key to indicate whether the stimulus was a real word or not. Each stimulus was played once in a random order. Both accuracy and speed were recorded.

Table 1
Experimental items for the auditory lexical decision task

Real word	Nonword
Pink	*Bink*
Pool	*Bool*
Bag	*Pag*
Boat	*Poat*
Tooth	*Dooth*
Tape	*Dape*
Depth	*Tepth*
Deep	*Teep*
Count	*Gount*
Cake	*Gake*
Gas	*Kas*
Golf	*Colf*

2.5. Autism-spectrum quotient

2.5.1. Materials

The Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) is a self-administered questionnaire designed to measure the extent to which adults with normal intelligence possess traits associated with ASD. Although this scale is not a diagnostic measure, its discriminative validity as a screening tool has been clinically tested (Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). In addition, traits as assessed by the AQ show high heritability (Hoekstra, Bartels, Verweij, & Boomsma, 2007) and are stable cross-culturally (Wakabayashi, Baron-Cohen, & Wheelwright, 2006).

The test consists of 50 items, made up of 10 questions assessing five subscales: social skill ("I would rather go to a library than a party"), communication ("I frequently find that I don't know how to keep a conversation going"), imagination ("When I'm reading a story, I find it difficult to work out the characters' intentions"), attention to detail ("I usually notice car number plates or similar strings of information"), and attention-switching ("I frequently get so absorbed in one thing that I lose sight of other things"). Half the questions are worded to elicit an 'agree' response and the other half, a 'disagree' response. These questions were designed to address demonstrated areas of cognitive characteristics in ASD (American Psychiatric Association, 1994; Baron-Cohen et al., 2001). To date, all studies examining the criterion validity of these factors have uniformly found support for at least the 'social skill' and 'attention to detail' components, and some for the 'communication' component (Austin, 2005; Hoekstra, Bartels, Cath, & Boomsma, 2008; Hurst, Nelson-Gray, Mitchell, & Kwapil, 2007; Stewart & Austin, 2008).

2.5.2. Procedure

The test was administered as a pen-and-paper task. Participants were asked to answer the question as quickly as possible by circling their response on a 4-point scale ('strongly disagree', 'disagree', 'agree', and 'strongly agree'). The items were scored on a continuous (Likert) scale (1–4), rather than the 0/1 scoring which is sometimes used for this instrument, as this retains more information about the participants' responses and also increases the item–item correlations, scale reliability and validity coefficients (Austin, 2005; Muniz, Garcia-Cueto, & Lozano, 2005). A total AQ score is calculated by summing all of the scores for each of the items, with a maximum score of 200 and a minimum score of 50.

2.6. Mill Hill Vocabulary Scale

The Mill Hill Vocabulary Scale (Raven et al., 1988) assesses verbal intelligence. It consists of two list of words split into two sets of 34 words. The multiple choice form was chosen from set *B*. Participants were asked to select the correct synonym for each word from a list of six alternatives provided with a maximum score of 33.

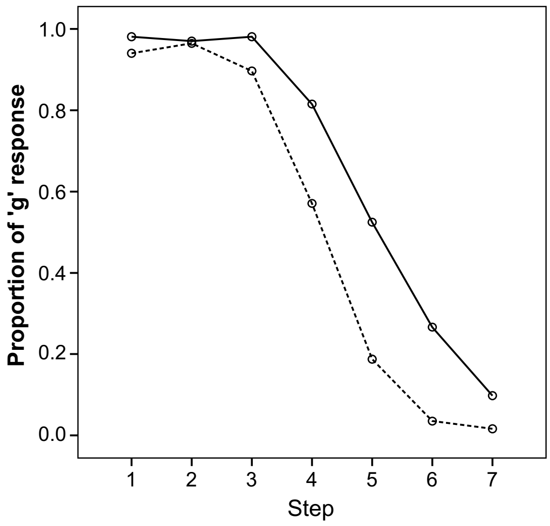

Fig. 1. Mean proportion of 'g' responses. The solid line represents the *'gift-kift'* continuum and the broken line the *'kiss-giss'* continuum.

3. Results

For the identification task, we have included data only from participants who showed identification functions with converging endpoints. A criterion was set so that those who interpreted the nonword endpoint stimuli as their word correspondent (e.g., [kift] as 'g' initial) more than 50% of the time were excluded. This resulted in the exclusion of data from 7 participants. The remaining data were subject to a repeated measures ANOVA using the mean proportion of 'g' responses as the dependent factor. A significant main effect of continuum [$F(1,47) = 391.87$, $p < .001$] was obtained, as well as a main effect of step $F(6,47) = 3441.15$, $p < .001$] and an interaction between the two sources [$F(6,47) = 321.52$, $p < .001$]. As illustrated by Fig. 1, the interaction was due to a pronounced tendency to judge items in the *gift-kift* continuum as being 'g'-initial than in the *giss-kiss* continuum in the intermediate Steps 4–6 – a pattern characteristic of a lexical identification shift (LIS) reported in the literature (e.g., Ganong, 1980). We measured the effects of LIS by subtracting the percentage of identifications at these steps in the *gift-kift* continuum from the counterparts in the *giss-kiss* continuum and calculating the mean of the three measures for each participant.

Descriptive statistics of other factors are summarized in Table 2. The distributions of AQ and Mill Hill Vocabulary

Table 2
Descriptive statistics of measured factors

Factor	Mean	Range	*SD*
Overall AQ	102	71–150	14.5
Auditory discrimination (% correct for the 30/50 ms stimuli)	76.7	25–100	21.0
Lexical decision (% correct)	94.3	79–100	4.7
Lexical decision (reaction time in ms)	1120	869–1790	162.4
Mill Hill Vocabulary	17.3	7–26	3.6

Table 3
Correlations between AQ, LIS and other factors ($N = 48$)

	LIS	Discrimination	Lexical decision (accuracy)	Lexical decision (RT)	Mill Hill
Overall AQ	−.304*	−.028	.251	−.065	.201
LIS	–	.171	.135	−.127	.013

* $p < .05$.

scores were typical of normally developing populations. The auditory discrimination score was highest for the 30/50 ms stimuli at 76.7%, which was significantly above chance level (one-sample $t(47) = 36.97$, $p < .001$). This region of peak performance is roughly in correspondence with the steps where the steepest incline in the identification function was found (around Step 5), indicating the relevance of the discrimination task to the identification task.

Table 3 shows the critical correlations between LIS, AQ and the other scores. A significant negative correlation was found between the overall AQ score and the LIS between the two continua. This relationship is illustrated in Fig. 2. Further analyses showed that the 'Attention switching' and 'Imagination' components of the AQ test correlated significantly with LIS [$r_s = -0.36$, $r_s = -0.31$, $N = 348$, $p < .05$, respectively]. On the other hand, no significant correlation was found between AQ and the Mill Hill Vocabulary score, the discrimination score (proportion of accurate responses), or the accuracy and reaction time in the lexical decision task. None of these variables showed a significant correlation with LIS either.

4. Discussion

In general, participants tended to shift their segment identification toward the real word end of the continuum (i.e., toward *kiss* rather than *giss*, and toward *gift* rather than *kift*). However, the effect was negatively correlated with the total AQ scores of the participants, consistent with our hypothesis that individuals with autistic traits are less likely to be affected by lexical knowledge in their phonetic perception. In other words, higher AQ was associated with a speech perception style that is less influenced by lexical information and more closely proportionate to the actual acoustic difference. Further analyses showed that the identification shift is related to the 'Attention switching' and 'Imagination' components of the AQ.

As an alternative explanation of the AQ-shift correlation, we raised the possibility that those with more "autistic" traits may have higher auditory sensitivity. However, there was no correlation between AQ and the performance in the VOT discrimination task. A second alternative explanation was that those with "autistic" traits are less accurate or slower to access lexical information. Again this does not appear to be the case, as the identification shift showed no relationship with the performance in the lexical decision task. Lastly, the degree of lexical involvement in the perception task may be influenced by the listeners' verbal intelligence. But verbal IQ was unrelated to the identification shift. The results are thus most consistent with the interpretation that the locus of the AQ-related effect is in

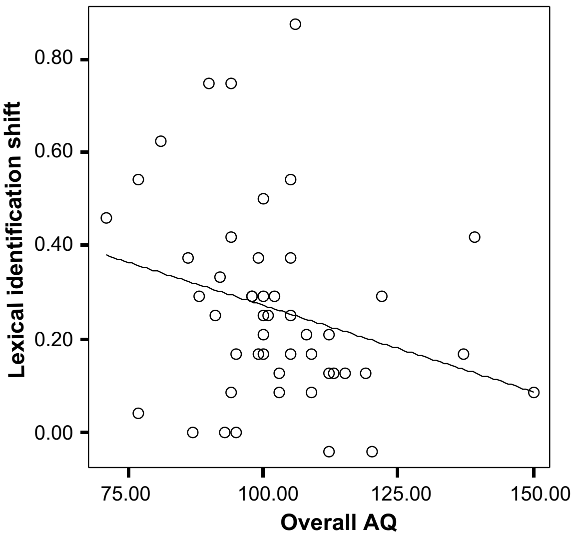

Fig. 2. AQ and identification shift.

the integration of acoustic and lexical information in phonetic processing.

Our finding follows the prediction of the theory of weak central coherence, which suggests that ASD is an extreme case of a cognitive style that is biased towards nonholistic information processing. The AQ-related lexical effect we found in speech perception can be seen as an example of such a bias that is revealed in neurotypical individuals. This systematic variation is best characterized as a difference in cognitive style, as with the reported pattern in degree choice where those with high scores on the AQ are more likely to be drawn towards science subjects than humanities and social science (Baron-Cohen et al., 2001). The outcome of our study may have implications not only for autism but also for the general relationship between speech and other cognitive processes. While it is acknowledged that speech perception is not immune from influence of other types of information, including the lexical status of auditory stimuli (Ganong, 1980) and visual cues to articulation (McGurk & MacDonald, 1976), it is still not clear how much of the observable variance in phonetic processing can be attributed to individual differences beyond aspects of cognition that are directly related to auditory or linguistic processes. Our study suggests the possibility that speech perception may not be encapsulated from higher order cognitive functions typically associated with personality traits.

Although our results support the hypothesis that higher AQ is associated with reduced lexical effects on speech perception, our conclusion requires some qualifications due to a number of limitations in the study. First of all, we only assessed two word-nonword continua. Although we may expect a larger effect if the number of continua were increased, the study bears replication using different test words to show that it is not a feature of these particular pairs. In this respect, it should also be noted that the words *gift* and *kiss* may have an emotional component. It is well documented that individuals with ASD show emotional processing difficulties (Hobson, Ouston, & Lee, 1988; Losh & Capps, 2006), and higher AQ individuals may have been less prone to emotionally respond to these ends of the continua.

Since the participants in this study were neurotypicals, whether the finding translates to diagnosed cases of ASD remains an empirical question. However, the fact that we see a connection between phonetic processing and autistic traits in such a cognitively and socially homogeneous population strongly suggests that a similar but more substantial effect would be found in a clinical group. As such, the results of our study provide sufficient impetus to investigate further the link between language and auditory processing in ASD and its connection with the general pattern of cognitive development in autism.

Acknowledgement

We would like to thank first and foremost the students of Heriot-Watt University who kindly took part in this study and the School of Life Sciences, Heriot-Watt University for supporting the research. In addition, we would like to thank Viktor Tron and Holly Branigan for valuable comments.

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