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Attentional Functions in Listening and Schizophrenia

A selective review

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Summary. Maintaining the focus on one sound object or shifting it to another are considered to be two important attentional functions in selective listening, which may serve to differentiate attentional deficits in schizophrenics with respect to their psychopathology. To avoid confounding attentional control with effects of cerebral organization (laterality) as in dichotic listening, it is suggested that spatial hearing is taken into account when testing these attentional operations.

Key words: Attention – Laterality – Listening – Schizophrenia

Introduction

Eye movements obviously have an intrinsic functional relationship to attention (Hirst 1986), as can be seen, for instance, in a study by Van Den Bosch (1984). In that study, a smooth pursuit deficit was found to be correlated with attentional deficits in various auditory tasks, including a complex auditory version of the Continuous Performance Test (CPT) and a measure of contingent negative variation in the preparatory-set paradigm in schizophrenics, but not – or not clearly – in other psychiatric patients and normal controls. Moreover, the assumption that there is a dual control of eye movements mutually inhibiting pursuit movements and saccades (Holzman 1987; Levin 1984) and enabling maintenance of the attentional focus on a (moving) target or shifting it to another one has an equivalent in the distinction between tonic response processes and phasic stimulus intake mutually inhibited by a dual attentional control system (Tucker and Williamson 1984).

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This selective review of work on listening and schizophrenia is guided by the idea that the notion or metaphor of a movable attentional "spotlight" or "focus" is useful in audition, too. Thus, hopefully not being too vaguely associated with the theme of eye movements and psychopathology, such a metaphor allows two important functions of attention in selective listening to be distinguished: *maintaining* and *shifting* the spotlight of attention. This relatively simple distinction, already used by Zubin (1975) with respect to reaction time deficits observed in the preparatory-set and modality-shift paradigms, makes an operationalization possible. This is one prerequisite for reliable recognition of psychopathological signs (Helmchen 1989), of two attentional deficits or aspects of attentional "ataxia" (Anscombe 1987): namely *distractability* (problems in maintaining) and *inflexibility* (problems in shifting). This distinction apparently has a pertinent relationship to schizophrenic psychopathology (positive/negative, paranoid/non-paranoid symptoms; Ulrich and Gaebel 1987), although assessment in a clear-cut way is complicated (Cohen and Borst 1987).

Investigation of attentional functions in listening, in particular with regard to speech, has to deal with laterality. Hence, following a brief account of selective listening and laterality issues in general and of listening problems in schizophrenics, a slight modification of the well-known "dichotic paradigm" (cf. Beaumont 1987) is proposed, to obtain perhaps less ambiguous data about schizophrenics' attentional problems. Based on the assessment measures and classification used, these attentional problems are sometimes related to the negative syndrome (Andreasen 1985; Nuechterlein et al. 1986), positive syndrome (Walker and Harvey 1986), thought disorder ranging from incoherence to poverty of speech (Bilder et al. 1985), inappropriate affect (Liddle 1987) or poor outcome after 7 years (Knight et al. 1986).

Attention in Listening

Listening, in contrast to hearing, refers to the active, attentional component of audition. As Scharf (1989) points out, signal detection is improved if the listener knows what (e.g. expected frequency) he is to listen for. "Knowing where a sound is coming from seems to provide little help to detection" (p. 6), but enhances processing of sounds and speeds up discrimination responses. Frequency and directional effects on sound detection and discrimination suggest effects of "early" attentional processes (e.g. Alho et al. 1987) in terms of Näätänen's evoked potential approach, or of "filtering" in terms of Broadbent's theory (cf. Kahneman and Henik 1981). In listening, an attentional spotlight also seems to grasp acoustic objects defined by pitch and location, as is argued in recent studies exploring spatial components of auditory attention (Rhodes 1987; Okita 1987). "Later" selection or "pigeonholing" controls this spotlight by maintaining it on one sound object or shifting it voluntarily to another one.

With respect to the role of spatially organized input on selective listening, research has consistently shown that spatial separation of competing messages first reduces problems of peripheral sensory masking and involuntary shifts to other sound sources, while pitch separation has less force and semantic structure may have the same organizing force, as location on selectivity (cf. Hawkins and Presson 1986). Therefore, it can be concluded that *spatial* aspects of attention (be they considered as letting loose, grasping, maintaining, or changing an object) play a crucial role in listening as they do in vision (cf. Possamai 1986). Research, showing the facilitation of auditory localization by eye movements (e.g. Platt and Warren 1972) or the influence of strong visual biases on localization (cf. Welch and Warren 1986), confirms the preponderance of vision for spatial information, evidently operative even in audition. So it seems plausible that for the attentional part of audition the same frontal (Bridgeman 1986) and related posterior brain systems as in visual attention (Posner and Presti 1987) might be involved.

Listening is influenced by hemispheric processes as well, typically indicated for most right-handed subjects by a "right ear advantage" (REA) for verbal stimuli in the *dichotic listening* task (e.g. Springer 1971), interpreted as expressing left hemisphere dominance for verbal processing (Geffen and Quinn 1984). Taking into consideration the multitude of variables influencing direction and amount of performance asymmetries (e.g. handedness, sex, developmental age, psychopathology, type and complexity of task stimulation, response demands, appropriateness of laterality indices), the utilization of the dichotic task to discover structural asymmetries has often been critically assessed (e.g. Efron 1985; Kerr-Hahn 1987; Geffen and Quinn 1984; Bradshaw et al. 1986). Originally the dichotic task was introduced as a tool in attentional research by Cherry (Egeth and Bevan 1973; Leahey 1979). Therefore, the very important fact has been pointed out that this method confounds attentional processes with cerebral organization (e.g. Bryden 1978; Hiscock and Stewart 1984). Perceptual asymmetries were found to be due to involuntary attentional processes; the REA for verbal input, for instance, seemed to be based on left-hemisphere-biased attention to the contralateral auditory hemispace (Studdert-Kennedy 1975; Geffen and Quinn 1984; Bradshaw et al. 1986). In line with these intricacies, models were sought that take into consideration structural, dynamic and processing-stage aspects of information processing and attention (e.g. Gopher and Sanders 1984; Tucker and Williamson 1984; for schizophrenia, Gjerde 1983).

In sum, attentional functions in listening comprise maintaining and shifting operations of the spotlight to sound objects based on their physical (spatial and frequency) properties, rendering further processing of informational content possible. These functions can be brought into action voluntarily, but are typically influenced as well by involuntary (e.g. orienting response, cf. Rohrbaugh 1984) or automatic processes (e.g. laterality-based perceptual preferences) or by priming and expectancy (cf. Johnston and Dark 1986).

Listening Problems in Schizophrenics

In a questionnaire study by Phillipson and Harris (1985), 44% of 73 remitted schizophrenics reported auditory distortions (alternations of familiarity, loudness and pitch) and felt reduction of these troubles early in drug treatment. From another viewpoint, Kugler (1983) summed up her report on auditory dysfunctions in chronic schizophrenics with "peripheral sites of disorder are unlikely" (p. 490). Other authors using similar measures (pure-tone threshold, impedance, threshold decay, etc.) did not find peripheral dysfunction either (Bruder and Yozawitz 1979; Collicut and Hemsley 1981), or (presumably state-dependent CNS-mediated) higher pure-tone thresholds (Taylor and Abrams 1985), or lower right than left ear thresholds (Gruzelier and Hammond 1979; Kugler 1983). Kietzman et al. (1985) emphasized that results of sensory studies in psychopathology might be biased by higher-order processes. Other, more central measures including dichotic click summation, Staggered Spondaic Word Test (Bruder and Yozawitz 1979), chord perception (Caudrey and Kirk 1979; Green 1986), assessment of speech perception with word association tests (Silverstein and Harrow 1980), syntactic click and semantic gist paradigm (Grove and Andreasen 1985) did not show definite auditory deficits in schizophrenics. With respect to phoneme discrimination, however, the performance of schizophrenics and depressives seems to be lowered (Caudrey and Kirk 1979), especially with dichotic presentation (Kugler and Caudrey 1983). Green (1987) reported that most psychiatric patients suffer from "binaural interference", i.e. presenting a story to both ears hampers comprehension more than intake at one ear only. Kugler (1983) found less successful sentence identification for chronic schizophrenics, if competing input was louder than the target sentence; this was also apparent under dichotic separation, where normal performance was 100%. Done and Frith (1984) found raised thresholds for words presented without context, if masked with noise.

These difficulties in speech discrimination might perhaps point to auditory sensory gating deficits, described for schizophrenics and bipolars by Freedman et al. (1987). This deficit should be distinguished from attentional dysfunction. For example, Waldo et al. (1988) reported that unmedicated schizophrenics and 50% of their relatives have an early evoked potential (EP) component allegedly indicating this gating deficit. But while schizophrenics' N100 amplitude, indicating attentional filtering, is diminished, those of their relatives with a gating deficit have even larger than normal amplitudes. Poorer attentional skills in subjects vulnerable for schizophrenia must apparently operate by over-arousing greater amounts of sensory input, having consequences not only for attentional filtering but also for ongoing selection of information, subsequent learning and coping. This is one key argument in the recent information processing model of schizophrenia of Carr and Wale (1986).

Problems with attentional demands in monaural and binaural auditory detection tasks have been demonstrated in EP research (Pritchard 1986), showing deviant later positive as well as earlier negative components (e.g. Barrett et al. 1986; Blackwood et al. 1987; Roth et al. 1981). In particular, Baribeau (Baribeau-Braun et al. 1983; Baribeau 1987), using a dichotic non-verbal target detection task, has reported EP-indicated deficits for medicated schizophrenics in maintaining the attentional spotlight under a slower stimulus presentation rate when instructions demanded focusing of one ear input only, but also when adaptations of focus or shifts between the two ears were called for in line with divided instruction.

Turning now to psychological studies of auditory attention in schizophrenics with regard to maintaining and shifting operations on the one hand, and type of psychopathology on the other, performance deficits were found in a series of studies. Using the *digit-span* test of Oltmanns and Neale (1975; under the distracting condition irrelevant digits were spoken by a male voice in the intervals between the female-spoken target digits), Oltmanns (1978) found differential performance deficits with respect to the matched non-distracting task in thought-disordered schizophrenics and partly in manics. Green and Walker (1986), Harvey et al. (1986a), and Walker and Harvey (1986) did not find distraction deficits in schizophrenics with negative symptoms, but did in schizophrenics with positive symptoms; performance deficits were also found to be associated with positive thought disorder and poorly semantically organized utterances. For both manics and schizophrenics, Harvey et al. (1988) reported distraction deficits and their correlation with positive, but not negative thought disorder (the last being observed only in schizophrenics). For schizophrenics, but not manics, they found that distraction performance correlated with positive thought disorder 4 days later, apparently indicating that in schizophrenics, unlike manics, distractability may not be considered as a mere function of the severity of positive thought disorder or psychopathology. Brenner (1983), using a dichotic version of the task, found an increase in performance under distraction for paranoid and non-paranoid patients, if the intensity of the target voice was increased; Rund (1982/83) in another modified version found only non-chronic non-paranoids to be more distractable, but not paranoids, who were actually less distractable than normals. These digit-span deficits, envisaged as probably indicating vulnerability by Harvey et al. (1986b), indicate that there are more problems in maintaining the appropriate focus, if positive (particularly thought disorder) or non-paranoid symptoms are prevalent.

Another series of studies used the *dichotic shadowing* technique, where response demands obviously strengthen maintenance of focus. Pogue-Geile and Oltmanns (1980) reported no shadowing deficit, if subjects were instructed to ignore contralateral input, but recall of semantic content of the shadowed message was diminished in contrast to manics, depressives and normals, and also more insertion errors of irrelevant words were observed for schizophrenics. Straube and Germer (1979) did not find shadowing impairment in acute paranoid and non-paranoid schizophrenics. However, Hemsley and Richardson (1980) reported that shadowing a binaurally presented message, which could not be separated by clear-cut physical cues (voice, location) from a distracting message, but only by semantic content, is abnormally reduced in schizophrenics in comparison with depressives and normals. Wahl (1976) observed more errors in non-paranoids, and more recall of distractors by paranoids; Schneider (1976) reported that delusional, but not non-delusional schizophrenics were more distracted by the non-shadowed input, the more its semantic content had a personal reference to the patients. For paranoid patients, especially those with delusions, Spring (1985) found more phonemic intrusions from the non-shadowed input into their otherwise unimpaired utterances, while non-paranoids showed a shadowing decrement under distraction. In sum, apart from general capacity reduction in the studies of Pogue-Geile and Oltmann (1980) and Hemsley and Richardson (1980), these shadowing experiments have found more subtle problems in maintaining focus, especially for paranoids, whose shadowing performance is apparently more prone to intrusions from other sources.

Another approach (Cornblatt et al. 1985) showed deficits in an audiovisual pointing task while disturbed by noise or a competing voice telling a story, for acute schizophrenics with positive symptoms (and depressives), but not for patients with negative symptoms. Green (1985) found lower word detection rates in a dichotic task under focused, but not under divided instruction, for acute schizophrenics with positive symptoms. Lower detection rates for syllables embedded in speech when distracting voices were added and most clearly when one voice (instead of 2 or 4) had to be faded out were reported for positive schizophrenics by Harris et al. (1985). Rappaport et al. (1972) found abnormally increasing omission rates for unmedicated acute paranoids, if the distracting source became increasingly noisier, while unmedicated non-paranoids omitted more signals, only when noise was less obtrusive. Irrespective of noise level, both schizophrenic subgroups had constantly higher false-alarm rates than normals. Neuroleptic medication improved detection for paranoids, but not for non-paranoids.

Altogether, these studies point to problems in maintaining focus, i.e. distractability for more acute, positive-symptom schizophrenics, but also to apparently different types of distractability in non-paranoids and paranoids. Magaro (1984) has characterized the paranoid processing style as being more controlled, i.e. attempting to maintain the attentional focus even under difficult external and internal conditions, while non-paranoids demonstrate a more automatic style, i.e. shifting the attentional spotlight in a less controlled way.

For negative and possibly chronic schizoprenics, deficits in listening are less obvious. Although cognitive performance is often reduced, especially with more complex demands, as in divided attention or dual tasks as in the study of Cornblatt et al. (1985), where the subjects had to accomplish the picture pointing task while listening to the content of the story, recall deficits but not distractability were found to be correlated only with negative symptoms. With a digit-span test, no distraction deficit was found for negative patients (Green and Walker 1986). Regardless of the preponderance of positive or negative symptoms, chronic patients had lower word detection performance under focused as well as divided dichotic instructions (Allen 1982). Much work has been carried out with visual versions of the CPT, a test of sustained attention (Nuechterlein 1985). Nuechterlein et al. (1986) reported attentional deficits with the CPT, correlating it with the amount of negative symptoms, as indicated by the BPRS Anergia score, but not with positive pathology. A CPT deficit in remission was observed for patients with negative symptoms at admission. Green and Walker (1985) found negative symptoms associated with lower performance on tests for the assessment of visual motor and spatial skills, while positive symptoms were related to deficits in verbal tests. Performance deficits in chronic and possibly more negative schizophrenics have been characterized by reduced processing capacity (Nuechterlein 1985) or more specifically as a result of "narrowed attention" (Broen 1977), or "minimal scanning" (Silverman 1964), considered as a protective deficit to reduce overstimulation. This points to a second important argument in the model of Carr and Wale (1986): shifting of attention is reduced, while maintenance may or may not be sufficient in chronics or negatives, respectively.

With respect to *laterality*, different hypotheses of altered hemispheric asymmetry in schizophrenics have been proposed (see reviews by Bruder 1983; Gruzelier 1985; Nasrallah 1986; Taylor 1987; Walker and McGuire 1982). An REA for verbal material in dichotic tasks has sometimes been observed in schizophrenics, too, being more pronounced in male, paranoid, and hallucinating patients (e.g. Lishman et al. 1978; Nachshon 1980; Colbourn and Lishman 1979; Takahashi et al. 1987). On the other hand, Wexler and Heninger (1979) found, in a dichotic syllable perception task, less lateral asymmetry for acutely ill schizophrenic, schizoaffective and depressive patients, normalizing or increasing with symptom remission. Niwa et al. (1983) reported greater performance decrements in a dichotic non-verbal detection task for the right ear than for the left, if attention was sustained over a longer time.

Regarding the above-mentioned difficulties with dichotic tasks in laterality research in general, different results or interpretations of asymmetries are not surprising. For example, Lerner et al. (1977), using a dichotic digit-span task (divided instruction), reported that apart from poorer performance in patients as compared with normals, chronic schizoprenics were able to recall more digits than acute schizophrenics. With respect to attentional response strategies employed by subjects when repeating the digits, normals and non-paranoids (particularly acute) made more shifts between the two digit sets according to the ear of presentation than paranoids, who apparently used a more organized strategy (i.e. grouping the digit sets according to the ear of entry) and showed greater REA than other groups, irrespective of chronicity. While these results were originally interpreted within an attentional framework, Nachshon (1980) re-interpreted the same data, now pointing to the twice as great an REA for paranoids compared to nonparanoids as well as the overall greater REA for patients than normals thus supporting the assumption of left hemisphere "overactivation" in schizophrenia. However, it could also be true that a laterality, however altered (aside from resulting in poorer performance), goes along with the observed active response strategy of paranoids in this task; in contrast, non-paranoids apparently seem to follow more passively automatic shifts to the right ear. In both cases, a greater REA can be expected because of the usual automatic preference for verbal input coming from the right. The hybrid nature of the dichotic task, which would require modification, might also be illustrated by an interesting study of Riedo and Hobi (1986). They used a modified dichotic paradigm with consonant vowels (CV) as stimuli and found that 5 young medicated schizophrenics with more than 2 years overall hospitalization demonstrated immediate recall of as many or even more CV from the ear not to be attended compared with that to be attended, if a shift from one ear to the other was demanded in the instructions. This was not the case for 12 healthy subjects and 7 medicated psychotic patients with an average overall hospitalization of only 2 months, who recalled more CVs from the ear to be attended. Recall performance in schizophrenics was only worse when stimuli were spoken into the left ear, but not when spoken into the right ear. These patients apparently had difficulty in short-term adaptation of the attentional spotlight, particularly if an active shifting to the left ear was demanded. This deficit points to hemispheric influences on shifting the spotlight, resulting not in an REA, but in a left ear disadvantage.

Conclusions

As, because of lateralization, shifting attention to the right apparently does not equal shifting to the left, which also seems to be true for maintaining attention (cf. Niwa et al. 1983), investigation of these two attentional activities should provide equal hemispheric starting points for assessing automatic and controlled portions of processing. For healthy subjects with monaural presentation of competing speech (one female, one male speaker) under divided instructions, Bradshaw et al. (1981) found shorter detection times for the right than the left ear, and generally faster detection than with dichotic presentation. This physical separation of two sound sources could be attained not only with respect to frequency (male/female), but more efficiently by location (cf. Hawkins and Presson 1986). The two attentional functions could then be tested within one hemispace, making the dichotic lateralization a *binaural localization* task with unilateral, but spatially distant and consequently separated competing stimulation. Distractability then could be defined in a more general way as uncontrolled shifting of the spotlight to other sound objects (possibly characterizing a non-paranoid deficit) or stronger influence of linguistic (phonemic, semantic) content of other sound sources during maintenance of focus (perhaps denoting the paranoid deficit). Inflexibility could be defined as reduced shifting to other objects with sometimes detrimental effects on performance (maybe characterizing chronic patients with negative symptoms).

In this review, the metaphor of an attentional spotlight implicating movement was used as a conceptual tool to point to one important background variable other than laterality for investigations in selective listening: spatial audition. Although the discussion took place on a more general level than in eye movement research, it may be assumed that there could be a neurophysiological equivalent of attentional functions in the ears as well.

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