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Article *in* Perceptual and Motor Skills · September 1999

DOI: 10.2466/PMS.89.5.315-326 · Source: PubMed

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Perceptual and Motor Skills, 1999, 89, 315-326.

PERCEPTUAL RESTORATION OF MISSING SOUNDS IN A GROUP OF HALLUCINATING SCHIZOPHRENICS[1]

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Summary.—17 subjects diagnosed with schizophrenia and having auditory hallucinations in their case history were compared with 15 control subjects in an experiment on perceptual restoration. A tone pattern was presented, then interrupted by noise, under conditions such that the tone pattern could be heard as going on continuously (restoration). A series of 16 stimuli with a distractor of varying amplitude (noise) were presented. Healthy controls reliably reported restoration in Presentations 9 and 10. Four schizophrenics reported no restoration at all. Three of them reported restoration earlier than controls, and four others reported it later than controls and continued to report the phenomenon after a point at which no healthy controls did. Six others presented an irregular pattern of response to the phenomenon. The results are discussed with respect to the neurophysiological functioning of the auditory pathway and schizophrenic symptoms.

Sound events are important signals for the survival of humans and animals. Therefore the auditory apparatus has been developed to detect subtle stimuli or events. This has been accomplished by the organization of separate and specialized processing of the electrical response to time disparities, intensity, phase differences, and frequencies. This separation is accomplished by simple division of the flow of action potentials as well as through more subtle processes, e.g., by means of different coding mechanisms and specialized cell functions.

Restoration

The continuity effect or continuity illusion is a process of perceptual induction based on time and amplitude relations. It may be generated by alternating one weak with one strong sound. The weaker sound will then illusively seem to go on behind the stronger sound, i.e., seem to be continuous. According to Bregman (1990), it is not possible to "stop" this perception by concentration or will, and therefore the phenomenon has been denoted primitive in contrast to other so-called schema-based phenomena resting on cognitive processes.

Various psychoacoustical explanations for this effect have been put for-

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ward. One model, adopted by Thurlow and Elfner (1959), assumes the facilitation of ongoing activity to be a result of excitatory postsynaptic potentials. Houtgast (1971) proposed that the nervous activity corresponding to the weak sound has to reach the level of the nervous activity of the noise before the continuity effect will be extinguished. Warren (1970) suggested that peripheral units stimulated by the louder sound must include those which are stimulated by the anticipated fainter sound. It seems now to have been established that the inducer (distracting sound) must contain at least the same frequencies as the inducee (stimulus sound). In the experiments still more conditions must be taken into account for the phenomenon to appear, e.g., duration, pauses, etc.

Evidence for the importance of facilitation and inhibition may be found in several sources. Lüscher and Zwislocki (1947) showed effects of adaptation, i.e., a rise in threshold, after stimulation with loud tones. Sachs and Kiang (1968) demonstrated an inhibition of auditory nerve fibre response after a second stimulation. Carterette, Friedman, and Lovell (1969) also presented evidence for such 'edge effects', i.e., the sensitivity of the perception may be altered in the borders of an adjacent sound event. Later, Houtgast (1971) documented lowering of the threshold in the edges of the frequency band of a test tone under various noise conditions. Moore (1988) has described further alterations of sensitivity in edge processes related to masking. At a neurophysiological level the demonstration of edge effects by inhibition and facilitation has been experimentally demonstrated by Evans and Zhao (1993) for the nucleus cochlearis. From a psychophysical point of view, these findings support the view that alterations of threshold at the edge of stimuli may involve redundant electrical activity in the nervous system which can create illusory perceptions.

Further findings are interesting, e.g., release from masking, to which the continuity effect has a close connection. Sachs, Winslow, and Blackburn (1988) found a changed discharge pattern in the frequency spectrum of the nucleus cochlearis due to activity in the contralateral part of the nucleus of Oliva. Thus, they showed evidence of a neurophysiological mechanism of an efferent releasing process already at this level. More efferent systems may contribute also. Weinberger and Diamond (1988) have for instance shown that the corpus geniculatum mediale converts the flow of action potentials after short plastic restructuring due to learning.

When reflecting on these alterations of reactivity of the neurons due to adaptation and the presence of other stimulation, one might imagine how restoration could take place. For instance, reinforcement of edge processes and efferent interactions may in certain circumstances reconstruct a neural excitation which replaces that of the missing sound.

Auditory Distortion in Schizophrenia

Schizophrenics report many distortions of auditory perception. In the trema-phase as defined by Conrad (1958) misperceptions of origin or intensity of sounds are reported, as for instance hearing music may be reported in terms of patterns that are not important for an ordinary listener. It is generally believed that in the apophany phase, auditory hallucinations are developed which later on are interpreted as parts of various cognitive and affectively loaded schemes. They become ego-syntonous and distort the sense of reality ending in autistic and often bizarre ideas of environment and ego. In contrast to nonschizophrenic hallucinations (organic, toxic) the schizophrenic ones are less organized into complex scenery or continuous stereotypic patterns, even if this may happen during later stages of the illness, as Walter, Prodreka, Steiner, Suess, Benda, Hajji, Lesch, Musalek, and Passweg (1990) have pointed out.

This study will deal with a psychoacoustical mechanism and its possible relation to the schizophrenic illness. The purpose of the study is to investigate the previously described integrative function of perception called restoration. It will be compared to a set of data from another psychoacoustical test performed on the same occasion by the same subjects (Nielzén & Olsson, 1997). This was an experiment on streaming. Two scales with varying amplitude in a series of presentations were crossing each other. When the amplitudes were equal, a perception of one upper layer of tones and one lower layer of tones took place for all control subjects; however, schizophrenics rarely perceived this perceptual streaming. In both the streaming test and the restoration test the presentation was made 16 times (serially), and all subjects of the control group reported the phenomenon streaming and restoration at the 9th to the 10th test. The preliminary finding of substantial aberrations in streaming became the incentive to direct the experimentation to the subject of this study, concerning a similarly elementary psychoacoustical function.

We assume that weaknesses of perceptual grouping may be related to the development of hallucinations and that schizophrenics should present with hallucinations even in periods of remission. Schizophrenics with hallucinations typical for their illness and their case history were compared with subjects of a reference group.

Method

Stimuli

Two stimuli were created for this experiment, probe tones and noise. A single probe tone was constructed of 12 added sinewaves. Its amplitude envelope was shaped according to the following equation:

$$y(x) = x^{\alpha} \quad \ln\left(\frac{x}{x_{max}}\right) \quad ;0<\alpha<1$$

where y = intensity and x = time.

To allow shortening of single tones, the sound was input to a sampler. A total pattern was translated into a continuous sequence by randomly changing eight tones with the frequencies of 220, 233, 240, 261, 277, 293, 311, and 329 Hz of the fundamental. The tones were of different durations (M = 76 msec., SD = 9 msec.; range 61–98 msec.). The random aspect is very important because any regularity will trigger pacing mechanisms within the auditory system and diminish the possibility of hearing the restoration. Therefore some of the tones were allowed to overlap and sometimes to be discontinuous by a few milliseconds.

The noise was constructed by the use of the software MATLAB (1992). The tonal pattern and noise were combined as in Fig. 1. The stimulus was presented over a period of 8.94 sec. During this time two pauses in the tonal pattern occurred, one after 2.74 sec. and the second after 5.89 sec. from the beginning of the stimulus. These pauses had a duration of 0.41 sec. During the pauses noise was presented immediately after and before the tone. The amplitude envelope of the noise had a square characteristic, i.e., the amplitude stayed at a constant level throughout its duration. For the present experiment, 16 stimuli were constructed with the noise increasing and decreasing in amplitude from the first to the 16th stimulus. The change of amplitude was made by 3-dB steps from 63 dB for the first stimulus to 84 dB for the eighth and ninth, and then by decreases of 3 dB stepwise to the end.

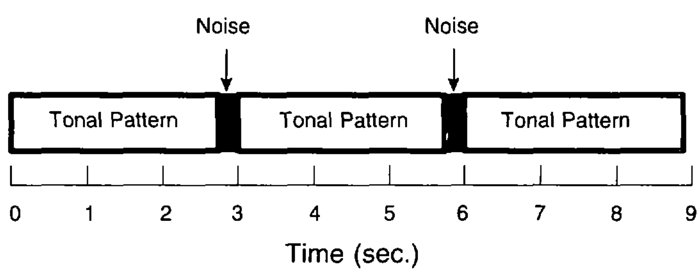

FIG. 1. Description of the test. A total pattern is interrupted by two pauses which are filled with broad-band noise

Equipment

The complex sound was constructed by the use of MATLAB (4.2) with Signal Processing Toolbox. The computer used was a Macintosh Quadra 650 with a built in PowerPC 601 card. The sound was sampled into a Kurzweil K2000 and MIDI-controlled by the software Digital Performer on a Macintosh LCIII. Recording for the test was made on a Teac W-900RX cassette-recorder, and the experiment was presented via the same cassette-recorder, a Yamaha CA610 stereoamplifier, and two Heybrook HB1 loudspeakers.

Procedure

The subjects were seated in a laboratory at a distance of 1.5 meters from the loudspeakers. The loudspeakers were placed in azimuth ±45°. The 16 stimuli were delivered in mono mode to the speakers. Before the test the subjects were given the opportunity to become familiar with the experiment by verbal and written explanations. Then they listened to examples of a presentation until they agreed that they had understood the experiment. The subjects were asked to mark an O when they could perceive a pause in the tonal pattern and an X when they could hear the tonal pattern go on through the noise. None of the subjects declared that they could not understand the meaning of the experiment.

Subjects

Seventeen former inpatients at the University Hospital in Lund (9 women, 8 men) were asked to take part in the study. The inclusion criterion was a diagnosis of schizophrenia with typical schizophrenic auditory hallucinations in the case history. The diagnosis had to have been established on clinical examination by a senior medical doctor and to be in accordance with the criteria of DSM-IV (American Psychiatric Association, 1994). The diagnostic procedure was not accomplished by use of scoring instruments. Exclusion criteria were organic brain diseases, alcohol or drug abuse, or the presence of additional psychiatric diagnoses. A formal consent was ascertained in accordance with the requirements of the ethical committee (LU 171-94). A detailed presentation of background data including medication, duration of illness, etc. is in Table 1.

The control subjects were recruited among medical students and staff. There were eight women and seven men; their mean age was 31 yr.; and the standard deviation was 7 yr. Among 17 originally recruited controls two had to be excluded as their reports strongly deviated for unknown reasons. No scoring for psychopathology was made regarding the reference subjects, and they were not matched for background variables. Distributions by sex and age (tested with χ^2) were not statistically significantly related to ratings among schizophrenics or control subjects.

An attempt to control for anxiety as a confounding factor was made. Anxiety is common among schizophrenics and could influence the results. A sample of eight patients with panic disorder, according to the criteria of

TABLE 1
SOME IDENTIFYING AND BACKGROUND VARIABLES OF SUBJECTS WITH SCHIZOPHRENIC SYMPTOMS

Ind. No.	Age	Sex	Medication mg/week	No. of Admissions	Duration of Illness, yr.	DSM–IV Diagnosis	No. of Months as Inpatient
1	44	Male	Zuclopenthixole decanate 100	4	11	295.30	8
2	37	Female	Zuclopenthixole decanate 50	5	8	295.10	3
3	35	Male	Clozapine 4200	7	7	295.30	15
4	34	Female	Clozapine 350	8	4	295.30	14
5	22	Female	Perphenazine 84	1	3	295.10	1
6	27	Female	Clomipramine 525	4	8	295.40	15
7	46	Male		1	10	295.90	1
8	36	Female	Roxiam 4800	2	9	295.30	1.5
9	38	Male	Roxiam 5250	10	12	295.30	17
10	46	Male	Haloperidole depot 50	5	4	295.30	1
11	30	Female	Perphenazine 280	6	4	295.30	6
12	31	Female	Perphenazine 280	4	5	295.30	4
13	28	Female	Clozapine 2100	6	12	295.30	8
14	32	Male	Clozapine 1750	6	7	295.30	13
15	49	Female		0	1	295.30	0
16	33	Male	Clozapine 1750	2	12	295.30	7
17	34	Male	Perphenazine 84	1	2	295.30	3

DSM-IV, was included in the study. Their ages ranged from 30 to 55 years (5 women, 3 men).

A comparison was made among these three groups regarding responses to presentations of Stimuli 5 to 13, where report of the restoration phenomenon occurs for subjects of the control group. A Kruskal-Wallis test of variance was made on the sums of the restoration experiment scores (Xs) of the three groups of subjects (Schizophrenic subjects, $n = 17$; Control subjects, $n = 15$; Anxious subjects, $n = 8$). It showed a significant difference between the groups ($H = 16$; corrected for ties, $p < .01$). A pair-wise comparison of the sums of the restoration experiment scores (Xs) between the three groups yielded the following results: Mann-Whitney test of Schizophrenic vs Anxiety groups ($Z = -3$, $p < .01$); Schizophrenic vs Control groups ($Z = -3$, $p < .01$), and Anxiety vs Control groups (ns). The significant differences in the rank sums of the scores (Xs) among the groups of subjects quantify the impression gained from inspection of the tabulated frequency distributions. The Schizophrenic group differed from the other two groups. This supports other results indicating that in auditory experiments schizophrenia is associated with greater distortion than are other factors including various psychiatric diagnoses.

Another often-expressed doubt is that schizophrenics have great difficulties cooperating during experiments. However, even if their attention is clearly influenced by their illness, they typically can focus on detailed judgements. They also seldom change their convictions as do people inclined toward neurotic lying. Therefore, schizophrenics may well be reliable in circumscript experiments. This has seemed to be shown during many years of experimentation (cf. Nielzén, 1982; Steinberg, 1986).

For the purpose of obtaining some idea of the validity and reliability of general rating responses by schizophrenics, a paired comparison was made on their scores (Xs) in the streaming and the restoration experiments. A Wilcoxon signed-rank comparison across the (2 × 16) presentations of the two experiments showed that the responses were significantly different between the two experiments for schizophrenics ($Z = -2$, $n = 17$, $p = .02$ corrected for ties). Schizophrenics rate significantly differently depending on two psychoacoustical tests which is judged to make their responses suitable for the interpretation of the data in this study. This finding required a closer look into the structure of the differences.

The matrices of ratings of streaming and restoration by the schizophrenics were studied, and it was clearly seen, that the ratings were organized on the basis of correlations not only between single individuals but among groups of individuals. Systematic patterns of responses consisting of a few groups were discerned, common for the two experiments.

The pattern of responses were four, comprehending all schizophrenic subjects. Criteria for the four groups were set according to the following principles: Group I: No report of the phenomenon; Group II: Starting reporting the phenomenon at Presentation 4 or earlier, continuously reporting it to Presentation 12 but not further; Group III: Starting to report the phenomenon on Presentation 5 or later, continuously reporting it until Presentation 13 or later; and Group IV: Intermittently reporting the phenomenon. The consequence of applying these criteria is that each one of the schizophrenic subjects falls only into one of the categories in the streaming or restoration experiment.

Results

The frequency distribution of the individual responses to the 16 presentations shows that the schizophrenics have reported less restoration than the subjects of the control group (Table 1 and Fig. 2). The α is set to .10 in the perspective of a power analysis of the streaming experiment. The expected effect size was 1.3 and the power .94 for the 0.5 level. This justifies a higher level of significance (with a caveat regarding the small over-all sample) in the restoration experiment performed at the same time as the streaming experiment by the same subjects (Altman, 1991).

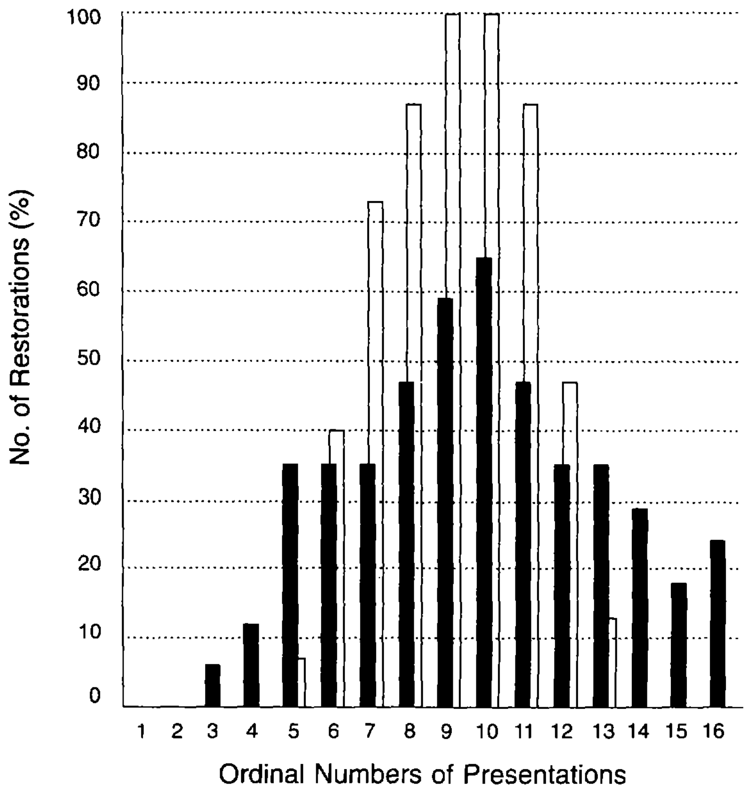

FIG. 2. Frequency distribution of individuals who reported hearing the tone-pattern as continuous at any one presentation (abscissa). □ = reference group ($n = 15$); ■ = schizophrenics ($n = 17$)

The shape of the frequency distribution resulted from a sum of four different patterns of response. Four of the schizophrenic patients did not report any restoration at all ($n = 4$). In another subgroup they reported a restoration earlier ($n = 3$) and in still another one they ($n = 4$) reported restoration later than the subjects in the reference group. Finally, some schizophrenics quite unsystematically reported restored sound intermittently ($n = 6$) (Table 3). Taken together this means that no single schizophrenic proband showed a pattern of response corresponding to that of the subjects of the control group. In the latter group an increasing number of the subjects reported restoration from Presentation 5, all reported it at Presentations 9 and 10, and then there were fewer reports of restoration until Presentation 14, for which no restoration was reported.

Table 3 shows the results as grouped in patterns of response in the ex-

TABLE 2
NUMBER OF XS (REPORTS OF HEARING RESTORATION) FOR 11 CRITICAL STIMULI OF 16 PRESENTATIONS TO TEST GROUPS

Group	*n*	Presentation									
		5	6	7	8	9	10	11	12	13	14
Reference	15	1	6	11	13	15	15	13	7	2	0
Schizophrenic	17	6	6	6	8	10	11	8	6	6	5
χ^2		1.84	.01	3.23	3.92	5.68	4.40	3.92	.09	1.05	3.23
p		.17	.92	.07	.04	.02	.03	.05	.77	.31	.07

periment of restoration and in the one on streaming. It may be seen that similar patterns of response have been assessed in the two experiments and that probands show intraindividual changes between the two experiments.

TABLE 3
DISTRIBUTION OF SCHIZOPHRENIC PROBANDS BY DIFFERENT PATTERNS OF RESPONSE IN TWO PSYCHOACOUSTIC EXPERIMENTS

Test	Group I No Restoration/ No Streaming	Group II Early Restoration/ Early Streaming	Group III Late Restoration/ Late Streaming	Group IV Intermittent Restoration/Streaming
Restoration	1, 7, 9, 11	3, 4, 14	2, 13, 5, 15	6, 8, 10, 12, 16, 17
Streaming	4, 5, 6, 7, 11	8, 16, 17	2, 3, 10, 13	1, 9, 12, 14, 15

Note.—Numbers refer to individual subjects listed in Table 1 above.

DISCUSSION

Before going into the discussion of the main results of the study a comment will be made on method. As argued above, the restoration and streaming responses appeared to be valid because they were significantly different from one amplitude to another and between the two experiments. When the data were classified according to different patterns of response, the differences regarding the schizophrenics' responses between the two experiments became clear. Proposing the hypothesis that all schizophrenics would respond by the same strategy of response in the two experiments, the results in Table 3 show that such an hypothesis must be rejected. Only individuals number 2, 7, 11, 12, and 13 did so. The probability of five out of 17 (versus all 17) falling into a group responding by the same strategy is .02 according to Fisher's exact test.

Beyond strengthening the measure of validity, another important point can be drawn from the comparison as well. The two tests seem to be unequal because, if a schizophrenic subject reports an aberration in some aspect of streaming, the same subject does not aberrate in the same manner in the restoration experiment. An interpretation may be that two separate psychoacoustical systems have dealt with streaming and restoration, respectively, and that there are varying severities of dysfunction between these systems in the group of schizophrenics.

The main finding of this study is that significantly fewer restorations are reported within the Schizophrenic group (Table 1). From Fig. 2 it looks as though there could be just a quantitative difference between similar response patterns of two groups; however, the distribution of the responses by the schizophrenics appears instead to be an organization of different patterns of responses, with both interindividual and intraindividual differences between them (see Tables 2 and 3). In fact, no schizophrenic subject's responses was like those of any subject in the reference group.

The patterns of responses for the 17 schizophrenic subjects may be separated into four groups (see Table 3). One group (I) never reported hearing restoration, while a second group (II) reported restoration early. A third group (III) started reporting restoration late and continued to report it after the reference subjects did not. The last group (IV) reported restoration intermittently.

We interpret the results as indicating that the subjects in Group I "resisted" hearing the restoration in the sense that they heard the sounds exactly as they were constructed but did not sort the stimuli into the usual psychoacoustically organized perceptual pattern. This may be taken as a sign of a profound aberration, which we argue mainly takes place at low levels in the nervous system and is perceptual rather than cognitive. The subjects in Group IV likely have a weakened and discontinuous experience of restoration indicating an incomplete functioning of the psychoacoustic perceptions. One might interpret these two ways either as an inherent malfunctioning correlated with the schizophrenic illness or a malfunctioning due to adaptation following the disease. Evidently the schizophrenic subjects have not presented a psychoacoustically accurate treatment of the sound stimuli, suggesting they have difficulty in the creation of "reasonable" percepts against a background of familiar and earlier sound experiences.

Only a few subjects reported restoration before it could be heard by the control subjects (Group II). This may be explained by the well-known increased sensitivity to various kinds of afferent stimulation especially in certain stages of schizophrenia, also described as "enhanced sensory awareness" (Freedman, 1974). A few schizophrenics (Group III) continued to report restoration for an unusually long time. A plausible interpretation would be to look at it as an effect of rigid habituation, as it is known that schizophrenia is associated with obsessive or perseverative mechanisms of adaptation (compensation for the original deshabituation). Such a strengthening of adaptation might, from a psychoacoustic point of view, help them better handle their environment by reducing chaotic overload (Swerdlow, Braff, Taaid, & Geyer, 1994).

As mentioned in the introduction, restoration appears to be a complex neurophysiological process which involves competition between other processes such as adaptation, processing of frequency and amplitude, masking, and grouping from redundant electrical activity in the brain. Restoration is a phenomenon which in clinical praxis is called illusion. The step to hallucination from illusion may represent a further dissociation of perceptual processes. The weakening of restoration among many schizophrenics may be related to the development of auditory hallucinations when the person becomes very ill. To corroborate such an hypothesis much research has to be done on all the neurophysiological and psychoacoustical subprocesses mentioned here. Regrettably, very little of this has been done in research on schizophrenia.

In conclusion, the observations concur with the familiar perceptual disruption and discontinuity in schizophrenia. Less restoration was reported by the group of schizophrenics than by the control subjects. There also probably are differences in functioning between various psychoacoustical systems within individuals with schizophrenia.

REFERENCES

ALTMAN, D. G. (1991) *Practical statistics for medical research.* London: Chapman & Hall.

AMERICAN PSYCHIATRIC ASSOCIATION. (1994) *Diagnostic and statistical manual of mental disorders.* (4th ed.) Washington, DC: Author.

BREGMAN, A. S. (1990) *Auditory scene analysis, the perceptual organization of sound.* Cambridge, MA: MIT Press.

CARTERETTE, E. C., FRIEDMAN, M. P., & LOVELL, J. D. (1969) Mach bands in hearing. *Journal of the Acoustical Society of America*, 45, 986-998.

CONRAD, K. (1958) *Die beginnende Schizophrenie, Versuch einer Gestaltanalyse des Wahns.* Stuttgart: Georg Thieme Verlag.

EVANS, E. F., & ZHAO, W. (1993) Varieties of inhibition in the processing and control of processing in the mammalian cochlear nucleus. In J. H. J. Allum, D. J. Allum-Mecklenburg, F. P. Harris, & R. Probst (Eds.), *Progress in brain research.* Vol. 97. Amsterdam, Holland: Elsevier Science. Pp. 117-126.

FREEDMAN, B. J. (1974) The subjective experience of perceptual and cognitive disturbances in schizophrenia. *Archives of General Psychiatry*, 30, 333-340.

HOUTGAST, T. (1971) Psychophysical evidence for lateral inhibition in hearing. *Journal of the Acoustical Society of America*, 51, 1885-1894.

LÜSCHER, E., & ZWISLOCKI, J. (1947) The decay of sensation and the remainder of adaption after short pure-tone impulses on the ear. *Acta Oto-Laryngologica*, 35, 428-445.

MATLAB. (1992) *High-performance numeric computation and visualization software, reference guide.* Natick, MA: The Math Works, Inc. Pp. 402-403.

MOORE, B. C. J. (1988) Dynamic aspects of auditory masking. In G. M. Edelman, E. W. Gall, & W. M. Cowan (Eds.), *Auditory function: neurobiological bases of hearing.* New York: Wiley Interscience. Pp. 585-607.

NIELZÉN, S. (1982) Music, mind and mental illness. Unpublished doctoral dissertation, Lund Univer , Lund, Sweden.

NIELZÉN, S., & OLSSON, O. (1997) Perceptual grouping due to pitch and amplitude in hallucinating schizophrenics. *Psychopathology*, 30, 140-148.

SACHS, M. B., & KIANG, N. Y. S. (1968) Two-tone inhibition in auditory-nerve fibres. *Journal of the Acoustical Society of America*, 43, 1120-1128

SACHS, M. B., WINSLOW, R. L., & BLACKBURN, C. C. (1988) Representation of speech in the auditory periphery. In G. M. Edelman, E. W. Gall, & W. M. Cowan (Eds.), *Auditory function: neurobiological bases of hearing.* New York: Wiley Interscience. Pp. 747-774.

Steinberg, R. (1986) Musikpsychopathologie. Musikalischer Ausdruck und pschische Krankheit. Unpublished doctoral dissertation, Ludwig-Maximilians-Universität, München.

Swerdlow, N. R., Braff, D. L., Taaid, N., & Geyer, M. A. (1994) Assesing the validity of an animal model of deficient sensorimotor gating in schizophrenic patients. *Archives of General Psychiatry*, 51, 139-154.

Thurlow, W. R., & Elfner, L. F. (1959) Continuity effects with alternately sounding tones. *Journal of the Acoustical Society of America*, 31, 1337-1339.

Walter, H., Prodreka, I., Steiner, M., Suess, E., Benda, N., Hajji, M., Lesch, O. M., Musalek, M., & Passweg, V. (1990) A contribution to classification of hallucinations. *Psychopathology*, 23, 97-105.

Warren, R. M. (1970) Perceptual restoration of missing speech sounds. *Science*, 167, 392-393.

Weinberger, N. M., & Diamond, D. M. (1988) Dynamic modulation of the auditory system by associative learning. In G. M. Edelman, E. W. Gall, & W. M. Cowan (Eds.), *Auditory function: neurobiological bases of hearing*. New York: Wiley Interscience. Pp. 485-512.

Accepted August 16, 1999.