

# Psychological Bulletin

## RESEARCH ON SENSORY INTERACTION IN THE SOVIET UNION<sup>1</sup>

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Since the early thirties the general area of sensory interaction has been the object of considerable attention by researchers in the Soviet Union.<sup>2</sup> However, owing to the language barrier and the near unavailability of the literature, most of the experimental and theoretical work that has been done in this field has gone unnoticed. Perhaps another factor tending to keep western attention averted has been the discouragement induced by the difficulty encountered in attempting to duplicate the reported findings.

It is true that much of the Soviet work on sensory interaction adheres to standards of execution, reportage, and interpretation that would be quite unacceptable to the western researcher. As a matter of fact, even a casual survey of the Soviet literature yields ready evidence of inadequate instrumentation and method-

ology, scanty detail, and a primitiveness in the statistical treatment of data which makes anything beyond an arithmetic mean a rare encounter.<sup>3</sup>

Nevertheless, western work on sensory interaction has been, in the main, scattered and desultory, whereas in the Soviet Union the subject has been given systematic and sustained attention (172, p. 77). For this reason alone a survey of the claimed experimental findings and of the correlative theorization seems to be in order.

The writer proposes first to outline representative basic findings, then to discuss the conditions that are said to affect interaction among the sense organs, and finally to sketch the theory that has been developed to account for this interaction. By

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<sup>2</sup> Some western students of Soviet psychology have seen in this the hand of Marxist ideology (13, pp. 161-162). The real reasons for the concentration of research in this area, however, are probably more on the pedestrian side. The writer discusses them in a paper to be published elsewhere.

<sup>3</sup> The published reports and resolutions of various professional meetings (not to be confused with the stage-managed affairs of the Lysenko variety), along with the abstracts of the discussions following the reading of papers, provide a frank admission of some of these deficiencies (5; 15, p. 805; 59; 109; 116-118; 172, p. 55; 198, p. 387; 347; 382; 484; 485; 486, p. 249; 487, p. 157; 488, p. 623; 489, pp. 650-651; 492, p. 715; 495, p. 330). Recently standard deviations and coefficients of correlation have been making a spotty reappearance after their exit from the psychological scene in 1936. Tests of significance are still only occasionally encountered (13; 88; 197, p. 45; 257, pp. 79-80; 335; 339, p. 402).

research in sensory interaction<sup>4</sup> will be meant generally investigations that explore modifications of response in one sense organ under direct stimulation when another sense organ has been or is subject to its own characteristic stimulus. The latter stimulus is referred to in the Soviet literature as "indirect" (*nepriamyi*) or "accessory" (*pobochnyi*)—the last being the preferred term in this paper. Excluded for the most part from the survey will be intersensory research on (a) sense organs in pathological states (12, 75, 77, 153, 196, 475–477, 479); (b) nonsensory reactions (electrical and ionic excepted) of the sense organs;<sup>5</sup> (c) binaural interaction (1, 2, 197); (d) binocular and other intramodal interaction (pertinent exceptions being made, however);<sup>6</sup> (e) the effect of pain, as the accessory stimulus, on sensory response (375, 393, 474); and (f) the influence of interoceptive stimulation and dermal irradiation (62, 63, 135, 162, 179, 185, 187, 191, 314, 315, 317, 321, 355). The writer wishes it to be understood that all statements of ostensible fact in the paper refer to data or interpretation of data generally accepted as valid in the Soviet literature. The survey covers the period from 1930 to the present.

#### CHANGES IN SENSORY RESPONSE UNDER ACCESSORY STIMULATION

##### *Absolute Sensitivity of Peripheral Vision*

The absolute sensitivity of peripheral vision was early shown to under-

go modification with excitation of the nonvisual organs (34). Modifiability of peripheral sensitivity was demonstrated also with excitation of the central visual system which, together with the peripheral system, constitutes the visual apparatus. Thus, illumination of the macular field was found to reduce sensitivity of the peripherally placed rods shortly after cessation of the stimulus (68, 73, 75, 93, 172, 286, 294, 326, 402, 403).

The antagonistic relationship surmised to obtain between the central and peripheral retina has been the subject of considerable study with results confirming and extending earlier findings (325, 329, 357–359, 403, 480). For example, it was noted that illumination of the central retina has no effect on the retinal periphery in the color blind, whereas, in those whose cone apparatus is non-defective, characteristic modifications of peripheral sensitivity are to be observed (265, p. 30; 357; 358). Thus, the reciprocal nature of the cone-rod relationship, which Orbeli had earlier hypothesized, came to be an accepted fact (69; 233, p. 473; 256, p. 47; 285; 371; 436–438).

While macular illumination, after its cessation, induces a reduction in peripheral sensitivity, a subsequent increase was found. Thus, after macular illumination with moderately bright light for one to ten minutes, a decrease in peripheral sensitivity for the first few minutes is exhibited, followed, however, by a period of supernormality (286–288, 400, 401).<sup>7</sup>

<sup>4</sup> Literally, interaction of the sense organs (*vzaimodeistvie organov chuvstv*).

<sup>5</sup> E.g., modifications of intraocular pressure, angioscotomata, etc. (384–388, 475–478).

<sup>6</sup> E.g., binocular contrast, various processes of retinal induction and sensibilization, simultaneous olfactory stimulations, etc. (3; 43–47; 48, pp. 209–215; 49; 53; 54; 111; 113; 128; 194; 195; 274, pp. 258–259; 451; 481).

<sup>7</sup> The first phase is considered as an instance of inhibition; the second, as one of disinhibition. However, "sensibilization" is not considered to be derived always from disinhibitory processes. Thus, the sensitizing action of threshold stimuli upon peripheral vision is ascribed to the increase of neural excitability caused by weak excitation of the visual apparatus (274, pp. 129–130, 185–186).

Not only does macular illumination of one eye effect a reduction in the sensitivity of its retinal periphery, but a diminution is to be observed likewise in the companion eye. Further study, however, revealed that more or less prolonged adaptation of one eye to moderately bright light results in a heightened peripheral sensitivity in the other, while increased central sensitivity is in turn reported subsequent to peripheral illumination. It was also established that preliminary adaptation of one eye to red light of low intensity heightens very markedly the peripheral sensitivity of both eyes (85-88; 117; 120; 143; 209; 216-218; 274, pp. 182-186; 286; 288; 289; 291; 292; 400; 402; 444; 472; 475).

Pronounced effects on the peripheral sensitivity of the visual organ have been demonstrated as a consequence of auditory stimulation (32, 78, 82, 137, 161, 178, 180, 183, 342-344, 345, 405, 446). For example, it has been shown that peripheral sensitivity, as a rule, declines on exposure to sounds of average or above average intensity. According to report, the noise of an airplane motor actually drops peripheral sensitivity to as low as 20 per cent of the level obtaining under conditions of quiet (32). However, a brief period of hyperventilation is held to restore peripheral sensitivity in spite of continued auditory action (94; 172, p. 118; 295; 296). Instances of heightened peripheral sensitivity have also been claimed (304, 319, 345), but later investigators have attributed these departures from the general rule to deviations from the subject's normal physiological state (137; 188; 274, pp. 186-187). However, exposure to ultrasonic frequencies (e.g., 32,800 cycles/sec.) has been reported to increase peripheral sensitivity (188).

As in the case of macular stimula-

tion, the same two-phase sequence of initial depression and subsequent elevation of peripheral sensitivity above normal—the latter phase a rather prolonged one—is to be discerned with auditory stimulation. This is true also when ultrasonic frequencies are employed (188; 274, p. 190).

Olfactory stimuli of various kinds have been observed to influence the level of peripheral sensitivity of the visual organ. The odor of bergamot oil and of pyridine in toluol, for example, are held to heighten peripheral sensitivity, although, where there were strong negative reactions to the latter, instances of lowered sensitivity are reported. Spirits of hartshorn are also said to increase peripheral sensitivity (48, pp. 281-286; 161; 183; 260; 274, p. 188; 345).

Similarly, gustatory stimuli of various kinds have been observed to influence the level of peripheral sensitivity of the visual organ. Weak sweet, salt, and acid solutions bring about an increase in peripheral sensitivity, whereas quinine brings on a decrease. The latter effect is, as above, attributed to the negative reaction of the subject to the bitterness of quinine (161, 186, 345).

Stimulation of the cold receptors is reported to produce a marked increase in peripheral sensitivity of the visual organ. For example, one minute after facial application of cool water, peripheral thresholds drop markedly. On the other hand, stimulation of the warmth receptors has a reverse effect, raising peripheral thresholds (66; 76; 172, p. 91; 183).

The effect of vestibular, intero-, and proprioceptive stimulation on peripheral sensitivity has been the subject of a number of studies. Interoceptive stimulation, arising from uteral expansion and distension of the bladder, is held to affect peripheral sensitivity adversely (172, pp. 109-

110; 185; 190; 191). Proprioceptive stimulation, evoked by muscular activity, is reported to induce varying effects: after light muscular activity, such as finger tapping at maximal rate or two minutes of gymnastic drill, an increase in peripheral sensitivity is noted; after heavy, fatiguing activity, however, a decrease ensues (34-40; 89; 91; 159; 172, pp. 91, 110-113; 185; 433). Postural stimuli exert varying effects on peripheral sensitivity of the visual organ: maximal sensitivity is elicited when the subject is comfortably seated; for the standing position it is considerably depressed (172, p. 118; 267). Vestibular stimulation—from rotation of a seated subject five or ten times—produces a significant decrease in peripheral sensitivity, with return to normality requiring periods ranging from 5 to 30 minutes (14, 96).

#### *Dark Adaptation*

Not only is peripheral sensitivity affected by various types of accessory stimulation, but so is the rate of dark adaptation. An accelerating influence on the process of dark adaptation has been reported from accessory stimulation of the cold, taste, and proprioceptive receptors; a similar effect upon accessory illumination of the eye with red light has also been reported (67; 157; 172, pp. 53-61; 288; 313; 316; 319; 401; 414).

#### *Absolute Sensitivity of Central Vision*

Considerable inquiry has been made into the effect of accessory stimulation on central visual sensitivity. From the research that has been done on this problem, it has been ascertained that auditory stimulation of moderate intensity heightens central sensitivity to white light for the dark-adapted eye, but that if monochromatic light is employed, the effect varies with the wave length

utilized. Thus, central sensitivity of the dark-adapted eye to blue-green colors is raised through auditory stimulation, whereas, to orange-red, it is decreased. Central sensitivity to extreme spectral red and violet, as well as to the yellow portion of the spectrum near 570 m $\mu$ , remains unchanged however (172, p. 118; 225; 227-234; 244; 250; 404).<sup>8</sup>

Kravkov, one of the foremost Soviet researchers in the field of sensory interaction, was able not only to demonstrate these effects over a considerable range of loudness, but also to show that the degree of effect varied directly with intensity of the accessory stimulus (244; 250; 274, pp. 270-273). He ascertained, further, that the observed changes in central sensitivity of the visual organ were a function of not only the intensity of the auditory stimulus but also of its duration. Thus, in an experiment to gauge the effect of sound on color sensitivity to green light, Kravkov found no effect from an auditory presentation of one-minute duration; however, he did note a pronounced effect on color sensitivity to green light following three minutes of auditory action.

The opposed character of color sensitivity to green and to red lights which is revealed when employing sound as accessory stimulus is disclosed also in experiments not involving auditory stimulation (263, pp. 35-39). For example, when the head is tilted back (postural accessory stimulation), it has been found that color sensitivity to green light (520

<sup>8</sup> Reverse accessory effects have also been noted on the central sensitivity of one eye when the other has undergone adaptation to red or green light. Adaptation of one eye to green light is reported to depress central sensitivity in the other upon accessory auditory action; adaptation to red light to elevate it (143).

$m\mu$ ) is always markedly decreased, proceeding after 90 minutes to 25 per cent of its original value, whereas color sensitivity to orange-red light (610  $m\mu$ ) exhibits an occasional tendency toward increase (267).

The direction of these effects is the reverse of that elicited with sound as the accessory stimulus. However, chilling, thermal, and gustatory accessory stimuli have been reported to induce directional effects similar to those elicited by auditory accessory stimuli. Here again, effects in the yellow region and the spectral extremes are not to be observed (74; 76; 245; 251; 256, pp. 48-49; 424).

The opposed character of color sensitivity to green and red lights is demonstrated more fundamentally by experiments of a quite different type. Kravkov and Galochkina, for example, were able to demonstrate the opposing modifications of sensitivity to green and red colors by passing a weak electric current through the eye with strengths of current ranging from 0.02 Ma. to 0.5 Ma. and times of action up to 15 minutes. Where anodal eye contact was employed, color sensitivity of the dark-adapted eye was increased for green-blue illumination, but decreased for orange-red. On employing cathodal eye contact, the effects were reversed. No change was noted as regards the extreme ends and yellow region of the spectrum (274, pp. 281-282; 280; 283). The effect of auditory stimulation on central sensitivity of the eye was thereby shown to be similar to that resulting from anelectrotonic influence—a fact to which considerable significance is attached.

#### *Differential Sensitivity to Brightness*

Several experiments have been performed which produced evidence of an effect of accessory stimulation on the differential sensitivity of the

eye to brightness (70, pp. 216-220; 98; 99; 274, pp. 216-220; 285; 292; 293). Illumination of one eye, it seems, makes for a simultaneous decrease in differential sensitivity of the other eye. Furthermore, the decrease is greater, the brighter the white-lighted field on which the latter is focused. The same effect can be obtained by keeping the brightness of the test field constant and increasing the brightness of accessory illumination (85, 86, 88, 216, 218).

Similar effects are elicited with sound as accessory stimulus. Thus, the brighter the viewed field, the greater the decrease in differential sensitivity under the effect of simultaneous auditory stimulation (274, p. 219); and very loud noise, such as that produced by an airplane motor, impairs markedly general brightness discrimination (32).

Accessory stimulation of the peripheral and central areas of the retina has also been shown to affect subsequent differential sensitivities. Thus, weak illumination separately of the peripherally distributed rods and cones acts to increase respectively the differential sensitivities of the centrally distributed cones and rods, while adversely affecting respectively those of their centrally distributed counterparts (274, pp. 220-221; 291-294).

#### *Critical Flicker Frequency*

Sensory interactional effects are evidenced also in the results of studies on critical flicker frequency (c.f.f.) under the influence of accessory stimulation (21; 76; 219; 220; 246; 274, pp. 357-370).<sup>9</sup> Kravkov, for example, noted that illumination of one eye with moderately bright light raises

<sup>9</sup> As was to be expected, accessorially induced changes in photic sensitivities parallel those noted in c.f.f., but with opposite sign (274, p. 365).

c.f.f. in the other, but wards off the reduction of c.f.f. that is usually observed in central vision of the other eye in the course of dark adaptation (274, p. 363).

It was demonstrated, in addition, that the effects of auditory stimulation on c.f.f. depend on the monochromatic nature of the light used. Thus, during the time of auditory action c.f.f. for green light (520  $m\mu$ ) is reduced, whereas for orange-red (630  $m\mu$ ), c.f.f. is raised. Here central retinal illumination was of such brightness as to produce critical flicker frequencies of 12–20 flashes per second. Accessory stimulation was pitched at 800 cycles at 85 db. On employment of white light as the primary stimulus, accessory auditory action was likewise found to affect c.f.f.: for central vision it is heightened, for peripheral vision lowered (220; 246; 256, pp. 49–50; 274, pp. 364–365).

Experimenters, employing the odors of bergamot oil and geraniol, ascertained the effect of olfactory stimulation on c.f.f. (251; 274, pp. 273–275). With brightness of flicker acting upon the central retina so as to produce a c.f.f. of 12–18 flashes per second for an eye at a given level of dark adaptation, the reduction of c.f.f. for green-blue illumination and its increase for orange-red under olfactory stimulation were established. No effects were noted for yellow (around 570  $m\mu$ ) or for extreme spectral red (690  $m\mu$ ) and violet (425  $m\mu$ ). Furthermore, upon cessation of accessory action, it was found that c.f.f. returned not only to previous levels, but having done so, frequently proceeded to exhibit relative frequencies the reverse of those previously obtained under olfactory influence. A similar picture of change in c.f.f. has also been disclosed upon accessory application of gustatory and thermal stimuli (76).

Reverse effects have been obtained by varying the intensity of light employed. Thus, if brighter light should be employed to bring the corresponding c.f.f. to 26–30 flashes per second, then under the action of the same accessory stimulation c.f.f. may change in the opposite direction to that obtaining for brightness marked by a c.f.f. of 12–18 flashes per second. In other words, if c.f.f. for weak light is reduced by accessory stimulation, then much brighter light may under the same conditions increase it (274, pp. 367–368).

#### *Visual Acuity and Irradiation*

A number of studies have been devoted to research on the effect of accessory stimulation on visual acuity (119; 209; 210; 214; 215; 233, p. 472; 256, p. 50; 265, pp. 26–29; 276–278). These show, for example, that where closely set, black forms are to be distinguished from each other against a white background, visual acuity is sharpened under accessory stimulation; but where the shades are interchanged, it is diminished. Of interest also is the fact that, upon monaural stimulation, especially marked effects are to be noted on the visual acuity of the contralateral eye (274, p. 187).

In irradiational terms one can speak of the increase of irradiational effect under accessory stimulation. Visual acuity in the above case may then be thought of as enhanced because, through increased irradiational effect under accessory stimulation, the white interspaces between the black forms crowded on a white background are rendered larger and the black forms are consequently better brought out. Where the shades are interchanged, the reduction of the black interspaces under accessory stimulation would explain the resulting diminution of visual acuity (214, 215, 276–278).

Whether the accessory stimulation be through light, sound, or odor, the increase of irradiational effect for white is demonstrable in every case. For example, increase of irradiational effect is induced by the odor of bergamot oil (214, 251), and under accessory auditory stimulation irradiational effect for orange-red increases (267, p. 34)—a finding which might not have been anticipated in view of the reputed decline of color sensitivity to orange-red under auditory stimulation. This fact is considered to be of importance in surmising a probable mechanism behind the action of accessory stimuli on visual afferentiation, and we will return to it later.

#### *Electrical Sensitivity of the Eye*

Electrical sensitivity of the eye<sup>10</sup> has been shown to be modifiable by the action of accessory stimuli (30, pp. 162-164; 70, p. 188; 94; 139; 410; 412; 415; 462; 463; 479). For example, illumination of one eye always raises the electrical sensitivity of the other. Auditory stimulation likewise increases electrical sensitivity, provided the sounds employed are not extremely loud, in which case electrical sensitivity is decreased (20, 30, 130, 132). Gustatory stimulation produces varying effects on the electrical sensitivity of the eye. Where sugar furnishes the accessory stimulus, electrical sensitivity is increased; where the stimulus is salt or citric acid, it is reduced. Under the olfactory action of bergamot oil increase in threshold of electrical sensitivity is reported to result (71, 72).

#### *Color Zones*

The boundaries of color zones have

<sup>10</sup> Electrical sensitivity of the eye is inversely indexed by the minimum strength of the applied current necessary to induce visual sensation (phosphene) on closing and breaking the circuit. Thus, the weaker the current inducing phosphene, the higher the electrical sensitivity of the eye.

been reported to shift under accessory stimulation. Thus, with lateral stimulation of the retina with bright light expansion of the red and yellow color zones and contraction of the green and blue zones result (105). With sound as accessory stimulus the zonal boundaries for green and blue are enlarged, those for orange-red drawn in, while those for extreme red remain as they are (144-146)—effects which are reminiscent of the changes, previously described, in color sensitivity brought on through accessory auditory stimulation.

Olfactory stimuli also have effects on the zonal boundaries (48, p. 281). If the odors of rosemary and indol are employed, expansion of the green region results with the former and its contraction with the latter. As regards the red zone, rosemary is found to contract, but indol to expand it—effects the reverse of those above. However, alteration of red zonal boundaries is not always observed (274, p. 275; 398; 399, pp. 389-396).

#### *Contrast*

Changes in visual contrast effects under the influence of auditory stimulation have also been the subject of investigation (446). The effects vary with the degree of contrast obtaining prior to accessory action. Thus, if a gray circular area on a white background is presented with a tone of 800 cycles at 75 db as accessory stimulus, contrast is heightened if the initial difference of brightness between the gray circle and white background is in itself great. On the other hand, contrast is diminished if the difference is initially small.

#### *Afterimages*

Accessory auditory stimulation has been shown to affect the course of extinction of visual afterimages (363, 364, 469-472). In a number of

people, for example, a strong auditory stimulus heightens the brightness of the afterimage, though hastening the termination of its course. Here the accessory stimulus precedes the inception of retinal illumination and is continued until extinction of the resulting afterimage. Sounds that are powerful enough to evoke fairly intense auditory afterimages tend especially to heighten the brightness of the visual afterimage. However, should an extremely loud tone be presented after the cessation of retinal illumination, the afterimage undergoes temporarily complete disappearance.

#### *Auditory Sensitivity*

While most research has employed light as the primary stimulus, a number of studies have been undertaken with sound performing the role. Here again effects of accessory stimulation have been demonstrated. Illumination of the eyes with white light, for example, is claimed to increase auditory sensitivity; absence of visual stimulation, on the contrary, decreases it. However, opposed effects are obtained by using, as accessory stimuli, different monochromatic lights. Thus, illumination of a white room with green light increases auditory sensitivity; but with red light it is decreased (182; 202; 312, p. 155; 351; 429).

Auditory thresholds are lowered also when the odors derived from geraniol and benzol supply the accessory stimulation (48, p. 281; 134; 267; 379; 380). Postural stimuli likewise are reported to affect auditory sensitivity. Thus, on tilting the head backward for any length of time auditory sensitivity is found to suffer. It is also reported that higher auditory sensitivity is obtained in the seated position than in either the

standing or horizontal position (172, p. 118).

Gustatory stimulation has been reported to improve auditory reception of low tones, but to worsen somewhat that of high tones. Established also have been the facilitating effects on hearing of accessory stimulation of the cold and proprioceptive receptors (172, p. 82; 366).

#### *Miscellany*

Comparatively little work has been done where the primary stimulus has not been visual or auditory (327, p. 763). But what work has been done shows the presence of accessory effects. Thus, it is averred, illumination of the eyes with white light heightens gustatory and olfactory sensitivity (48, pp. 253-254), whereas auditory stimulation reduces the electrical sensitivity of the gustatory apparatus (194; 267, p. 50). Electrical sensitivity of the gustatory apparatus, as well as its sensitivity to salt solution, is reported also to decrease in the course of dark adaptation of the eye. Mental activity, however, excludes the latter effect (48, pp. 140-141; 71; 72; 457).

Research on the accessory effect of the odors of geraniol and thymol on the vestibular apparatus discloses reverse effects. The odor of geraniol heightens vestibular excitability, prolongs rotary postnystagmus, lengthens the illusion of counterrotation, and shortens chronaxie, while that of thymol has the opposite effect (48, pp. 281-282; 150; 151).

#### SOME CONDITIONS AFFECTING SENSORY INTERACTION

##### *Strength of Accessory Stimulus*

Increase in strength of the accessory stimulus leads so frequently to effects that are the reverse of those induced by weaker intensities that



one can almost speak of a "rule of inversion" (67; 111; 161; 172, pp. 80, 88; 178; 184; 226; 263, pp. 39-41; 274, pp. 180-181, 190; 344; 448-451; 474). For example, sounds of weak intensity heighten the electrical sensitivity of the eye, while those of increasing intensity are accompanied by a gradual decline. However, Kravkov doubts the generality of any "rule of inversion" and points to one case where the rule itself is controverted. Varying the intensities of sounds employed as accessory stimulation, he found that an increase from 25 db to 95 db was paralleled by a steady increase of sensitivity to green light (530 m $\mu$ ) and a steady decrease to orange light (590 m $\mu$ )—findings which deny a general "rule of inversion" (267, p. 93; 274, p. 180).

#### *Excitatory State of Primary Sense Organ*

The effect of accessory stimulation depends not only on the intensity of the accessory stimulus, but also on the initial degree of excitation of the sense organ undergoing primary stimulation. Thus, in order to increase the loudness of a tone on accessory visual stimulation, the initial loudness must be sufficiently great. Otherwise, either no effect will be demonstrable or a loss in loudness will ensue. The example cited under *Contrast* in the previous section is another instance of the effect of initial degree of primary excitation.

#### *Duration of Accessory Stimulation*

Intensity of accessory stimulation is not the only factor of importance; duration is also important. Kravkov (130-132, 184, 344, 348) has shown that, as a rule, accessory effect becomes increasingly prominent during the first moments of accessory action. But subsequently the effect very of-

ten drops away from the maximum attained (274, p. 186). For example, accessory auditory stimulation was applied for a half hour while the eye underwent simultaneously 31 to 61 minutes of dark adaptation. Critical flicker frequency was found during this period to rise sharply, but to diminish after a quarter hour from the maximum previously attained (220).

#### *Termination of Accessory Stimulation*

In describing the influence of accessory stimulation on a given sense organ, it is, of course, necessary to stipulate whether the state of the latter is tested before or after cessation of accessory stimulation, since, after withdrawal of the accessory stimulus, its effect does not just wear off with an eventual return to normalcy. There frequently arises instead a shift in a direction opposite to that of the initial effect. Lowered sensitivity may be followed by a supernormal phase, heightened sensitivity by a subnormal (157; 274, p. 190).

For example, Kravkov observed that sound lowers c.f.f. for peripheral vision. After its termination, however, he noted that under the same experimental conditions c.f.f. is raised, sometimes markedly (220; 274, p. 364). As a further illustration, another experiment may be cited (405). Here, on testing the peripheral sensitivity of the eye after cessation of auditory stimulation, it was observed that a supernormal phase emerged subsequent to the decrease generally registered during the action of the accessory stimulus.

#### *Affectivity of Stimulus*

It appears that stimulus affectivity is a factor to be reckoned with in sensory interaction. For example, it has been claimed that, where gusta-

tory and olfactory stimuli of unpleasant character are applied as accessory agents, peripheral sensitivity of the eye declines (172, p. 88; 345). It is also reported that, after presentation of harmonious tones, color sensitivity of the dark-adapted eye to red and yellow is raised, to green-blue lowered, whereas disagreeable sounds reverse the effects (259, 426, 428).

#### *Physiological State*

The specific physiological state of the sense organs, as well as the more general physiological state of the individual, plays a role in sensory interaction (274, p. 169; 399, pp. 412-421; 455).<sup>11</sup> A number of experiments may be mentioned by way of example. In a previously cited experiment, it was shown that presence of a subject in a green-illuminated white room heightens auditory sensitivity, whereas presence in a red-illuminated white room brings about a decline. However, on changing the physiological state of the subject through moderate dosage of veronal, the experimental effects are precisely reversed. In the hyposthenic state induced by veronal, green illumination lowers, red illumination heightens auditory sensitivity (189, 429).

Similarly, it has been demonstrated that with intense auditory stimulation the electrical sensitivity of the light-adapted eye undergoes decrease, and that of the dark-adapted eye, increase (20; 139; 274, p. 188; 303). Electrotonic stimulation of the eye with anodal contact thereon (anelectrotonus) induces similar effects; with cathodal contact (catelectrotonus), however, reverse effects show up (274, p. 190; 411).

Instillation of adrenalin into the

<sup>11</sup> In various hypodynamic states, for example, the more usual effects of accessory stimulation tend to sharper expression (172, pp. 97-117).

eye has likewise been shown to bring on similar modifications in the electrical sensitivity of the eye: for the dark-adapted eye, electrical sensitivity declines; for the light-adapted, it increases (106, 303). Similarly, various accessory effects on electrical and color sensitivity can be made to reverse sign depending on whether the tested eye is light- or dark-adapted or whether it is adapted to green or red light (235, 240, 249, 268, 298, 415).

#### *Miscellany*

*Summation of accessory effects.* If each of two sense modalities, on accessory stimulation, induces an increase in peripheral sensitivity of the eye, their joint action induces an effect beyond that induced singly. If, however, the individual effects are in opposite directions, their joint action induces a general effect on peripheral sensitivity equal approximately to their difference (172, pp. 80-81; 181).

*Repetition of accessory stimulation.* Constant repetition over equal intervals of time of the same accessory stimulus has been found frequently to yield a diminishing effect which tends to zero (172, p. 81).

*Cumulation of accessory effects.* The effects of accessory stimulation linger in some instances so that on subsequent days the change in level of primary threshold is found to undergo successive increase (172, p. 81).

*Diurnal variation.* The respective sensitivities of the rod and cone apparatus exhibit an inverse reciprocity of accessory influence that is diurnally dependent. Thus, it has been shown that at midday, when central sensitivity is at its maximum, peripheral sensitivity is minimal. As a normal relation, degree of sensitivity of the one apparatus is inversely tied to

degree of sensitivity of the other (431, 436-438).

#### SOME THEORY ON SENSORY INTERACTION

In the attempt to comprehend the nature of the modifications of sensory response induced through accessory stimulus action, several considerations have been put to theoretical work. The result to date appears more a collection of eclectic plausibilities than an integrated set of relevant explanations. The following discussion will report what these considerations are.

##### *Contiguity*

Over a considerable range of auditory and visual stimuli certain visual and auditory responses undergo intensification through respective accessory reinforcement via intermodal action. To explain a number of them, such as the increase in visual acuity of one eye upon monaural stimulation of the contralateral ear, recourse has been had to the neurological map. In the region of the *corpora quadrigemina*, for example, the visual and auditory nerve fibers are in close proximity and myelin-free. Since nerve action in one unmyelinated fiber is held likely to influence that of another contiguous to it, the feasibility of excitatory irradiation through contiguity of the conducting fibers is considered to be demonstrated. The fact and feasibility of excitatory irradiation in the region of the *corpora quadrigemina* and also of the *corpora geniculata* seem to be justified, in the main, by reference to foreign work (6; 121; 152; 156; 265, p. 29; 274, pp. 187-188; 304; 319).

Similar considerations are thought to make olfactory influence on vision understandable, for in the region of the *stratum zonale* and *nucleus anterior thalami* the visual and olfactory

nerve fibers lie in close proximity. Thus, the olfactory afferent system may likewise have its effect on visual phenomena through excitatory irradiation.

The fact that there is anatomical proximity along the auditory and visual nerve pathways is also thought to make explicable many cases of synesthesia. On this basis the latter can be viewed as instances of sensory interaction (267, pp. 59-63).

##### *Neural Excitation*

The question arises as to whether it is better to view many instances of accessory effect as mediable through change in neural excitation rather than through change in neural excitability, that is to say, through threshold modification, although either alternative could conceivably account for a number of the intensifying effects produced by accessory stimulation. Kravkov and others, as a matter of fact, designed a number of experiments to throw light on just this point (265, pp. 26-29; 274, pp. 222-230).

It had been established earlier that the sensitivity of central vision to orange-red light declines with simultaneous auditory stimulation; that is to say, a rise of threshold or decrease of excitability takes place. Kravkov reasoned that, if on accessory auditory stimulation positive irradiation could, nevertheless, be demonstrated to intensify for an object of orange-red hue (if its apparent size was increased), then change not in neural excitability, but in neural excitation must be decisive for achieving the observed effects. If positive irradiation decreased, then change in neural excitability could be taken to operate as the major factor.

Experiment realized the former contingency—the effect of positive

irradiation was increased, a result leading to the conclusion that accessory auditory stimulation may add to visual excitation of certain kinds (257). Thus, on this basis, the data, relevant to both positive irradiational effects and visual acuity on accessory auditory stimulation, are held explicable.

Further support for the emergence of an accessory effect through change in neural excitation is derived from the fact that with accessory auditory stimulation increase of differential threshold is not accompanied by a seemingly necessary decrease of irradiational effect. It is held that this failure of prediction is also accounted for on the assumption of an accessorially induced upward modification of neural excitation which renders  $\Delta C/C$  greater in magnitude than  $\Delta I/I$ , of which it is the "central physiological correlate, . . .  $C$  and  $\Delta C$  being measures of excitation in the nervous centers" (274, pp. 222-225).

#### *Leveling and Accentuation*

Under the "rule of leveling and accentuation" a refinement, implicit in the foregoing, was explicitly introduced to allow a wider encompassing of disparate data (257; 263, pp. 31-35; 265, pp. 26-29; 274, pp. 225-230). This refinement consists in taking note of the initial contrast between the viewed object and its background. The following discussion points to this necessity.

It was shown that, with simultaneous auditory stimulation, visual irradiation of a white object against a black background intensifies, while that of a gray object against the same background diminishes (215). Here is an example of the kind of oppositely directed effects for which a unified explanation is needed. The rule of leveling and accentuation that has

been proposed aims to provide this: where initial contrast is large, accentuation of contrast occurs; where it is small, leveling or reduction of contrast results. The reasoning behind the rule is fairly direct and may be indicated by way of example.

Supplementary excitation of the visual apparatus on accessory auditory stimulation is not distributed uniformly over the visual field but is unevenly apportioned. Those regions of the visual apparatus which already are to a considerable degree excited, "attract to themselves" the major portion of the additional excitation; the less strongly excited regions share more modestly. In other words, the magnitude of supplemental excitation, accessorially induced, is a function of the excitation directly occasioned by the primary stimulus. Thus, on accessory visual stimulation loud tones should sound louder; weak tones should be little, if at all, affected. In this way the rule of accentuation is held explicable.

But why a rule of accentuation *and* leveling? Again an example will elucidate. It is known that differential thresholds for brightness discrimination increase with brightness. If there is little initial brightness contrast between object and background, accessory increase of excitation is about equally shared, so that, where the ratio of differential brightness may have been  $I_2/I_1$ , it is *centrally* now  $I_2 + \Delta E / I_1 + \Delta E$ ;  $\Delta E$  is taken as the "brightness equivalent of the supplementary excitation" and  $I_2 > I_1$ . This leaves the resulting difference in excitation about the same. The magnitude of the latter ratio, now less than the former, indicates, however, an impairment in sensing the brightness difference that obtains. Thus, brightness difference between object and background, initially contrasting little, comes to be even harder to ob-

serve with the result that a leveling tendency in brightness difference establishes itself (274, p. 225).

On the the other hand, should the initial contrast be very large, accessory increase of excitation accrues, in the main, to the brighter source as previously explained, so that the effect of contrast comes in this instance to be seen as exaggerated (353, 446).

Similar reasoning would account for the oppositely directed shifts in critical flicker frequency that are to be observed when accessory auditory stimulation is employed to reinforce flashes of low and high brightness respectively. Critical flicker frequency is increased when the brightness of flash is initially high; it is decreased when initially low. Here the flash is thought of as an object presented against a less bright background represented by the fading afterimage between flash phases (274, pp. 366-370).

#### *Intracentral Mediation*

An accumulation of experimental data (274), as well as the anatomical richness of intracentral connections, made natural the consideration of intracentral mediation as a factor in sensory interaction. Certain specific research seemed also to suggest the intracentral mediational character of accessory action. For example, in the course of registering the bioelectrical currents in the auditory region of the cerebral cortex of rabbits, it was discovered that these currents are modified in an interesting fashion, should the eye of the animal be exposed to regular flicker: the rhythm of electrical potential in the auditory region comes, after an interval, to correspond to that of the flicker (332). In addition, the facts of protopathic and epicritic sensitivities were taken also to demonstrate

the presence of central inhibitory action of some afferential systems on others. Thus, the tactile and proprioceptive systems, taken as phylogenetically of more recent origin, are seen as antagonistic in action to the systems giving rise to those sensations of gross temperature and diffuse pain which appear on disturbance of the inhibitory action of the former (265, p. 29; 327, p. 611; 371; 372, pp. 39-53; 375).

The widespread influence of the Pavlovian propositions of cortical action (since 1950 official dogma) has also had its effect in increasing the plausibility of intracentral mediation of accessory action (274, pp. 178-180; 338-340; 374, pp. 136-296). Thus, on the assumption of such mediation two possibilities present themselves: either excitation of a cortical center leads to excitation of another, modally distinct, or it leads to depression of the latter. Accessory effects may, therefore, be reinforcing or antagonistic.

It has previously been pointed out that central illumination raises peripheral threshold, while peripheral stimulation decreases central sensitivity. The relationship is mutually antagonistic, provided central vision is not that of the achromat, in whom an antagonistic influence is not exhibited due to cone deficiencies. Since central illumination of one eye, for example, affects adversely peripheral sensitivity in the other, it has been concluded that such effects, as indicated above, must, therefore, be intracentrally mediated (391).

Intracentral mediation of accessory action functions also to account for many of the reverse effects elicited upon increase in strength of the accessory stimulus ("rule of inversion"). The assumption is made that an initially weak accessory stimulus sets up two central proc-

esses: one positively inductive; the other negatively inductive. Upon increase in strength of the accessory stimulus, increases in the magnitude of the two oppositely signed inductive effects are given by two differently accelerated growth curves. Reversal of modal accessory effect is associated, therefore, with the change of sign resulting from algebraic summation of the two curves, once a certain magnitude of the accessory stimulus has been exceeded (274, p. 181).

#### *Ionic Balance*

It has been pointed out that under anelectrotonic influence central sensitivity of the dark-adapted eye to green-blue is increased, to orange-red decreased, whereas under catelectrotonic influence the reverse is observed. These changes parallel remarkably those resulting from the application of appropriate accessory stimuli and, hence, have been the subject of special study.

Attempts to explain the results of electrotonic influence have generally been based on considerations of ionic concentration and balance (274, pp. 281-286; 280, pp. 138-143; 415). In view of the known role of ionic calcium and potassium in the excitability of tissues, investigation turned first to them and later to ionic sodium and magnesium.

Since in a solution potassium ions are univalent and those of calcium bivalent, the former migrate to the cathode more rapidly than the latter upon application of direct current to a circuit. The value of the ionic index  $[K]/[Ca]$ , which measures the relative concentration of ionic potassium and calcium, increases, therefore, at the cathode; it decreases, of course, at the anode due to increasing concentration of ionic calcium there.

If ionic factors are involved in the reported modifications of central

sensitivity, it was reasoned that changes in the relative concentration of ions should be accompanied by changes in the various central sensitivities. Through iontophoresis<sup>12</sup> it was possible to introduce ionic calcium and potassium into the eyeball in order to test the surmise. Predictions were fulfilled (274, p. 284; 283): ionic calcium was found to increase sensitivity to green but to decrease it to orange-red, whereas ionic potassium was found to increase sensitivity to orange-red but to decrease it to green. Termination of the iontophoretic process reversed the respective effects (262, 281, 282, 284).<sup>13</sup>

Further experimentation showed that ionic sodium was similar in action to ionic potassium, while ionic magnesium was similar in action to ionic calcium (260, 376, 377). Hence, decrease in value of the ionic index  $[K]+[Na]/[Ca]+[Mg]$  is associated with increase in sensitivity of the green- and blue-sensing apparatus of the eye, while increase in value of the ionic index is tied to increase in sensitivity of the red-sensing apparatus.

Since ionic sodium and potassium are known to favor the concentration of acetylcholine in tissues, whereas ionic calcium and magnesium are known to lead to its reduction, it is considered very likely that various concentrations of acetylcholine exhibit respective optimal effects for the various color-sensing apparatuses of the eye (274, p. 284). In the last

<sup>12</sup> The introduction of ions into the body by means of electric current.

<sup>13</sup> Through iontophoresis it was found possible to neutralize certain accessory effects on central sensitivity. Thus, iontophoresis of sodium, which reduces central sensitivity to green (520 m $\mu$ ), neutralizes the accessory effect of auditory stimulation which, under ordinary conditions, heightens this sensitivity (275, p. 146).

analysis, then, central sensitivities are seen as dependent on ionically influenced acetylcholine concentration (275, pp. 143-145).<sup>14</sup>

#### *The Autonomic Nervous System*

A variety of accessory stimuli such as tones, noise, the taste of sweetness, the odor of bergamot oil, geraniol, and camphor has been reported to produce similar differential effects on retinal sensitivity to green-blue and orange-red lights: heightening sensitivity to the former, decreasing sensitivity to the latter (228, 234, 251). This circumstance led researchers to look for a common factor behind this discerned uniformity of differential action. They noted that application of the above stimuli was accompanied by a quickening of the pulse, and it was conjectured that the common factor might well be the autonomic nervous system, in view of the fact also that the odor of thymol, which reverses the differential effects cited above, was found to reduce pulse rate (8; 9; 160; 172, pp. 81, 88; 242; 252; 253; 256, p. 49; 265, p. 31; 399, pp. 412-419).

This conjecture among others led to experimentation which disclosed that the color sensitivity of the eye was changed in the reciprocal pattern mentioned above on direct instillation of adrenalin into the eye. Further research along these lines demon-

strated that sympathomimetic substances such as cordiamin, phenamine, sympathol, and ephedrine heighten sensitivity to green light for the dark-adapted eye, but lower it to red light. On the other hand, parasympathomimetic substances such as carbocholin, veronal, the berries of *Schizandra Chinensis*, and pilocarpine usually bring on reverse effects: sensitivity to red light is heightened for the dark-adapted eye, while that to green light is lowered. Ephedrine is reported to heighten also gustatory, olfactory, and auditory sensitivities (48, pp. 255-258; 112; 114; 115; 147; 148; 153; 252; 253; 274, pp. 276-278; 279; 303; 399, pp. 401-407).

Confirmation of the autonomic mediation of a number of accessory effects has been sought also in data from experiments involving electrical application to the eyeball. For example, it will be remembered that if direct current of weak intensity is passed through the dark-adapted eye with anodal contact, sensitivity to green-blue light is heightened with corresponding diminution to orange-red light—the characteristic antitethesis. The effects on sensitivities are reversed with cathodal contact (268; 274, p. 190; 280; 283; 411).

Now, it was pointed out that the relative concentration of calcium ions is increased in the vicinity of the anode during electrical action. Since increase in relative concentration of calcium ions, in a very great number of instances, is understood to induce effects similar to those of sympathetic excitation, the mechanism of the above accessory effects is held to be probably autonomic (262; 265, p. 33; 274, pp. 285-286; 282; 284).

Therefore, auditory stimulation, the odor of bergamot oil and geraniol, and the taste of sweetness are said to achieve their accessory effects through influence on the sympathetic

<sup>14</sup> Ionic calcium and magnesium are known to activate cholinesterase which through hydrolysis reduces acetylcholine content; ionic sodium and potassium, on the other hand, are known to suppress cholinesterase, thereby increasing acetylcholine content.

Interference with the acetylcholine chain of reactions, as through homotropization of the eye, stabilizes central sensitivities in spite of iontophoresis. Hence, strictly speaking, not acetylcholine, but processes involving it in an essential way are to be associated with modifications of central sensitivities (354, 377).

division of the autonomic nervous system with differential effects on the color-sensing apparatus of the eye; adverse effects are induced where parasympathetic excitation would instead ordinarily facilitate.

Corroboration of autonomic action has been sought in a variety of experiments. For example, backward tilting of the head for a period of time is claimed to bring about conditions favoring parasympathetic excitation. One should then expect a reduction of sensitivity to green light—an expectation which was confirmed (265, p. 32; 423).

It should be noted that the differential action of the two divisions of the autonomic nervous system on the green- and red-sensing apparatus is also consonant with the observed reciprocal action of green and red light on a number of physiological functions. For example, the internal ocular pressure of one eye is increased or decreased according as the other eye is illuminated with red or green light respectively (476, 477). A similar reciprocity of action has also been observed with hyperventilation which decreases sensitivity to green light while increasing it to red (296).

Certain changes in peripheral vision are likewise held ascribable to modifications of the autonomic state (8, 9). Thus, vestibular stimulation, which is said to favor parasympathetic excitation, was noted to worsen peripheral sensitivity (14). Backward tilting of the head is also reported to decrease peripheral sensitivity, which fact accords with the increase of parasympathetic excitation held attributable to the tilted position of the head. Changes in peripheral sensitivity have also been noted with alteration of relative ionic concentrations, electrically induced—a fact which again is taken to relate modification in peripheral

sensitivity to autonomic influence (283).

Further confirmation of the autonomic mediation of accessory effects was sought in experiments involving the cerebellum. For example, it was shown that subsection of the cerebellum to electromagnetic waves of ultra high frequency definitely altered the level of sensitivity for peripheral vision (334). Since, according to Orbeli, the cerebellum must be regarded as one of the main regulators of sympathetic nervous activity, the results of experiments such as the above were taken as tending to demonstrate the partial dependence of the visual apparatus on the autonomic nervous system (372, 383).<sup>15</sup>

While a wide variety of data is accounted for on the basis of autonomic mediation of accessory action, Kravkov points out that the initial drop in peripheral visual sensitivity on accessory auditory stimulation is an experimental datum which does not harmonize with all of the foregoing. Auditory stimuli appear to be sympathotropic as to effects: pulse rate is stepped up, the sensitivity of the green-sensing apparatus of the eye is heightened, the retinal blood vessels are constricted, etc. But peripheral sensitivity appears to be sympathotropically affected inasmuch as it increases under anelectrotonic conditions and decreases under vagotropic stimuli such as are provided by the backward tilting of the head. One should, therefore, expect a positive effect on peripheral sensi-

<sup>15</sup> Orbeli's theory of the "adaptive-trophic" regulatory action of the sympathetic nervous system on all tissues of the body, including the central nervous system and the striped musculature, has had a considerable influence on research in the field of sensory interaction (55; 69; 95; 123; 160; 162, p. 77; 173; 192; 193; 256, p. 46; 334; 336; 337; 368-374; 456; 468).



tivity through accessory auditory stimulation. The reverse, however, takes place. To account for this, Kravkov hypothesizes the existence of intracentral connections whose influence in an *ad hoc* fashion dominates antagonistically over those influences proceeding through the medium of the autonomic system (267, p. 81).

#### *The Green Receptors*

The fact that the application of either sympatho- or vagotropic accessory stimuli leaves unaffected sensitivity both to extreme spectral red and violet and to colors in the region of  $570\text{ m}\mu$  has led to the assignment of an especial role to the green-sensing apparatus of the eye. It is hypothesized that only if the green receptors are stimulated is accessory heightening or lowering of color sensitivity evocable (254; 256, p. 49; 266; 274, pp. 327-331; 352).

Throughout the spectral range of excitability of the green receptors (from  $430\text{ m}\mu$  to  $680\text{ m}\mu$  approximately) excitation of the green-sensing apparatus appears everywhere accompanied by accessory effects except in the neighborhood of  $570\text{ m}\mu$ . Reference to the three excitation curves of the three basic color receptors (*b*, *g*, *r*) shows that the ordinates  $Y_g$  and  $Y_r$  are about equal in the neighborhood of  $570\text{ m}\mu$ ,  $Y$  being taken as equal to degree of excitation. Since excitation of the green receptors is held to induce a positive accessory effect, the failure of accessory effect in the neighborhood of  $570\text{ m}\mu$  is ascribed to an initiated negative accessory effect of equal magnitude, induced by a simultaneous excitation of the red receptors.

Since magnitude of unsummed accessory effect is regarded as a direct function of degree of excitation of the respective color-sensing ap-

paratus involved, where  $Y_g > Y_r$ , the algebraic sum of the associated positive and negative accessory effects yields a residual accessory effect which is positive; where  $Y_g < Y_r$ , the residual accessory effect is negative; where  $Y_g = Y_r$ , accessory effect is lacking ( $430 < m\mu < 680$  approximately).

Excitation of the blue receptors is thought to enhance accessory effect on the condition that  $m\mu > 430$  approximately. Thus, in the neighborhood of  $520\text{ m}\mu$  where  $Y_b = Y_r$ , approximately, the inhibiting action of the red receptors is canceled out by the sensibilizing action of the blue receptors. This produces, accordingly, a positive accessory effect derived solely from stimulation of the green receptors, one which, as it turns out, is maximal.

On making the inhibitory and sensibilizing action of the red and blue receptors respectively explicitly dependent upon excitation of the green-sensing apparatus, the failure to elicit accessory effects at the spectral extremes ( $m\mu < 430$ ;  $m\mu > 680$  approximately) is made understandable.

To test the hypothesis that accessory effects on color sensitivity in trichromats are not observed without excitation of the green-sensing apparatus, an experiment was performed to see whether through central mediation accessory effects at the spectral extremes could not be elicited in one eye upon illumination of the other with green light. The results were affirmative, thereby confirming the special role assigned to the green receptors (253, 254, 352).

#### *Modification of Primary Conditions*

Accessory stimulation is held to produce its effect in many instances in ways not involving considerations of excitation or excitability of the primary sensory system. These refer

to accessorially induced modifications of the physical conditions under which primary stimulation is applied. For example, the pupillary reflex may respond to an auditory stimulus. Here the quick contraction of the pupil with its slow subsequent relaxation would be expected to modify some aspects of the visual function. Since the amount of light entering the eye is affected by pupillary width, upon nonemployment of an artificial pupil apparent changes in visual threshold which follow upon auditory stimulation may be ascribable not to changes in excitation or excitability of the visual afferent system, but rather to changes, induced by accessory stimulation, in the physical conditions. Since the pupillary reflex is not without effect on accommodation, visual acuity also may undergo modification owing to the accessorially induced changes in the physical conditions accompanying primary stimulus action.

Similarly, pain, vestibular stimulation, etc. modify the pupillary reflex and thereby may give rise to simulated accessory effects. As another instance, tactile stimulation around the ear appears to affect auditory threshold; but again, the result of such stimulation might more aptly be ascribed to reflex changes in the small muscles controlling the tension of the bony system of the middle ear than to changes in the auditory afferent system (267, pp. 87-88; 274, pp. 86-88).

#### *Conditioning*

The conditionability of sensory responses adds immensely to the range of sensory interaction and is considered a factor to be reckoned with though the accessory effect is not native but acquired. Work in the Soviet Union on conditioned "sensory reflexes" dates back to 1936

when Kravkov, Kekcheev, Bogoslovkit, and Dolin independently demonstrated the conditionability of changes in visual responses. Thus, it was early shown possible to condition changes in electrical sensitivity of the eye, critical flicker frequency, peripheral sensitivity, etc. to such indifferent stimuli as ticking, a tone, and elapsed time of eye exposure to the dark (16-18; 22-25; 50-52; 57; 79-84; 124; 169-171; 183; 202; 233, p. 474; 256, p. 53; 259; 263, pp. 41-43; 265, pp. 36-39; 267, p. 35; 274, p. 192; 309; 339; 381; 396; 417; 418).

To illustrate some of this work: Pshonik managed to induce changes in thermal sensation in response to accessory auditory stimulation by making of the latter a conditioned stimulus (57, 381). Dobriakova conditioned increase of gustatory sensitivity to the ticking of a metronome after having associated the latter with light—a stimulus which ordinarily induces a positive accessory effect on gustatory sensitivity. In addition, it was found that symbols, denoting stimuli which heighten gustatory sensitivity, make manifest like effects (71, 72, 171). A general heightening of various visual and auditory sensitivities has been observed to ensue through mere presence of a subject in the experimental room. Frequent prior presence in the room while in a state of intense attention is here said to condition modification of visual and auditory sensitivities to the sight of the experimental room—the state of attention being thought of as in the role of "unconditioned stimulus" (79; 80; 267, pp. 85, 111; 272; 274, pp. 192-194).<sup>16</sup>

<sup>16</sup> "Concentrated attention" has been assigned an important role in the sensibilization of the receptors. "Attentive practice" and expectation also lead to sensibilization, the former being held capable of doing so on a permanent basis (48, p. 209; 149; 172, p. 92; 274, pp. 230-231; 396; 408; 416; 460).

## CONCLUDING REMARKS

Soviet research on sensory interaction has amassed over the past 24 years a fund of data that, in spite of a deserved skepticism, cannot but strike one for its persistent consistency and "logical," though novel, character. This research appears to demonstrate that all modalities undergo various modifications of sensory response on appropriate application of an accessory stimulus and that, where the primary stimulus is visual, the resulting modifications conform to striking patterns.

Basic to one of these patterns is the fundamental role assigned to the green-sensing apparatus whose excitation is a requisite for the mediability of accessory effects through simultaneous excitation of the non-green receptors. Of the latter there are those which upon excitation are reinforcing for accessory effects, while others are depressive. Thus, where sensitivity to blue-green, for example, is heightened, that to orange-red is lowered; and vice versa.

The antagonistic relationship between color receptors is traced to inversely related ionic concentrations induced through autonomic nervous action brought into accessory play.

Thus, where ionic calcium predominates, sensitivity to green is heightened, to orange-red lowered; where ionic potassium predominates, reverse sensitivities obtain.

Other patterns of accessory effect and of reciprocal accessory action have been intensively investigated with characteristic results. However critical one may be of the Soviet studies, the cumulative results obtained with their apparent inner consistencies suggest, therefore, the worthwhileness of a re-examination of the whole problem of sensory interaction. Recent restrictions on types of psychological research in the U.S.S.R. in favor of "Pavlovian" methodologies and conceptions suggest that non-Soviet researchers are the ones to undertake the job (60; 201; 272; 338-341; 434, pp. 69-70; 473; 498-503; 505).<sup>17</sup>

<sup>17</sup> Signs point to a possible relaxation of dogmatic prescription of allowable methodologies and conceptions. Both Ivanov-Smolenskiĭ and Bykov, the official "Lysenkos" of Soviet psychology, physiology, and related disciplines, who in their ruthless advocacy of a raw Pavlovism have exercised great power in these fields since 1950, have recently been censured in *Pravda* along with Lysenko for suppressing the views of those holding conceptions "deviant" from theirs (440).

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