Journal of Experimental Psychology
1970, Vol. 83, No. 3, 458–464

INFLUENCE OF IMAGED PICTURES AND SOUNDS ON DETECTION OF VISUAL AND AUDITORY SIGNALS[1]

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The present study compared sensitivity for auditory and visual signals in a simple detection task and in a related task in which *S* was also imaging mental pictures and sounds. Sensitivity (*d'*) was reduced during imagery; within the imaging conditions, it was smaller when image and signal were both auditory or both visual than for cross-modal conditions and smaller with unfamiliar than familiar images. Likelihood ratio (*Lx*) was also smaller in the isomodal imaging conditions, as there were more visual false alarms during visual imagery and more auditory false alarms during auditory imagery. The data are not consistent with the assumption that *d'* is lower during imagery due to distraction; they do not entirely fit a channel competition model, but suggest that imagery functions as an internal signal which is confused with the external signal.

Perky's (1910) effect has been difficult to explain: she found that if *O*s were asked to describe their images of common objects while dim facsimiles of the objects were presented before them, they reported only an "imagery," not a "perceptual," experience. This finding seemed paradoxical: in ordinary situations, imagery can be distinguished from real stimuli virtually 100% of the time; yet Perky's *O*s confused external stimuli with the images they were describing and seemed unable to discriminate the real physical signals. It is possible to explain the seeming inconsistency between Perky's experiment and everyday experience by inferring that the two events are at antipodal points on a continuum. The continuum would represent a class of conscious events characterized by activity in the sensory pathways and some central expectancies and memories, encompassing both predominantly "imagery" and predominantly "perceptual" events (cf. Hebb, 1968; Neisser, 1967; Scheibel & Scheibel, 1962). In ordinary redundant experience, the images and percepts can be readily distinguished close to 100% of the time. For example, a red traffic signal occurring after an expected temporal interval at a busy intersection, where all the other cars respond to the signal, is readily perceived. However, a red traffic light on a long, deserted, and unfamiliar stretch of highway, when the driver is daydreaming, may go unperceived or be dismissed as "imaginary." In the extreme experimental conditions of Perky's procedure, where all the redundancies are absent and *O*'s expectancies are systematically distorted, judgments may be incorrect virtually 100% of the time, as she reported.

This suggests that Perky's (1910) effect can be viewed as a sensory decision, based on the probabilities inherent in the task. Using this conceptualization and applying the techniques and statistics of signal-detection theory (cf. Swets, 1964), Perky's finding has been confirmed. The *S*s were asked to detect visual signals, and they were also asked to detect these signals while describing their images of common objects. Their *d'*, the signal-to-noise ratio, was always lower during imaging than nonimaging detection tasks (Segal & Fusella, 1969; Segal & Gordon, 1969). It appeared that imagery interfered directly with reception

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[1] This research was supported by Air Force Office of Scientific Research Contract F44620-68-C0013. The authors are grateful to Eugene Galanter, whose advice led to more effective use of signal-detection design, to Ed Krupat, who assisted in the research, and to Jerome L. Singer, Crawford Clark, and Daniel Feldman, for their helpful comments in the preparation of the manuscript. Data from this paper were presented at the meeting of the Eastern Psychological Association, Philadelphia, April 1969.

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of the signal, the background noise, or both, confirming that imaging uses some sensory elements in common with perception.

An alternate explanation, however, could implicate a central attention factor; i.e., *S*s missed the signal when they were imaging because the image distracted them. The present experiments were planned to test these two explanations by comparing the effects of visual and auditory imagery on detection of visual and auditory signals. Presumably, a visual image and an auditory image are equally distracting; thus, if auditory and visual images block auditory and visual signals equally, a central factor of attention would be responsible. However, if differential blocking were obtained, then we could conclude that imaging directly interfered with perception due to some similarity of function between the two processes.

The basic hypothesis is that imagery and perception are similar processes, and visual imagery depends on specific activity in the optic system, while auditory imagery depends on activity in the auditory pathways.

EXPERIMENT I

Method

Subjects.—The *S*s were eight men, age 17–26, all undergraduate students at the City University of New York. All of them had already served as *S*s in a similar imagery experiment, and most were considered "good imagers." They agreed to serve as paid *S*s in the six sessions required.

Apparatus and stimuli.—Each *S* was seated in a comfortable chair in a lighted room. A large cone, constructed of translucent vinyl, was placed before *S*'s face so that he looked through the open base, while his gaze was restricted by its narrowing sides and by the 8-in. screen, subtending 19° visual angle, which replaced the point of the cone. The visual signal, a small blue arrow subtending about 6° of visual angle, was back-projected onto this screen from a small Accura projector attenuated by a Powerstat voltmeter. The projector was located in the same room and was activated by a silent mercury switch. The auditory signal, a harmonica chord, was played on a tape loop into *S*'s earphones; intensity could be adjusted by the volume control on the tape recorder (Concord 350). Although all *S*s were instructed to report only the sound of the harmonica chord, some detected the onset and offset of the tape itself and had to be instructed to regard that as "noise."

Procedure.—Each *S* served for six sessions and each session included a practice period, a discrimination task, an imaging task, and a second discrimination task. At the start of the first session, *S*s were told,

> In this experiment, we are going to measure your ability to detect signals, that is, to report the presence or absence of lights and sounds. You will be given many trials and asked on each whether a figure was present, a sound was present, or there was no signal at all. We will begin with some practice trials . . . so we can find the appropriate intensity for the sound and the figure. We will deliberately set the intensity at a level where it is difficult for you to make the discrimination and where you have some errors. Thus, no matter how good your sensitivity, you will be making errors. So just relax and do your best.

Practice. During the practice period of at least 50 trials, *S* indicated when he heard the sound or saw the figure. Intensity of the signals was systematically adjusted, and the practice period was prolonged, if necessary, until intensity levels were found at which *S* made between 5% and 25% errors. These levels were maintained for the remainder of the session.

Discrimination. The *S*'s sensitivity for these signals was then measured over 66 trials. The *S*s were told the following:

> Now we are going to continue with virtually the same procedure . . .. You will have a series of trials. On each trial, there will be presented either the visual signal, the auditory signal, or nothing. Each type of trial will be presented equally often. You will be given a ready signal to mark the start of an observation interval. Conclusion of the interval will be signified by my asking you, "What was it?" You may reply, "sound," "picture," or "nothing."

Each interval lasted 5 sec. and contained either a 2-sec. auditory signal, a 2-sec. visual signal, or no signal, presented in random order.

Imaging. Next, *S* was given the following brief introduction to imagery:

> You have already been a subject, and so you know that . . . images are mental pictures, and it is a common experience to have imagery when you are trying to remember a specific face or place. In the experiment today, we will also be concerned with auditory imagery. I am sure you have had the experience of imagining the sound of a particular song, the sound of someone's voice, the sound of the ocean. During the next procedure, you will be asked to imagine various things. The instructions will make it clear whether we want a visual or an auditory image. Please try very hard to experience your image in the sense requested. You will not be asked to report on your image, as we find it is easier for people to concentrate on their imagery

> when they remain silent. You will also be asked to detect the signals. You will be asked to imagine hearing, for example, a phone ringing. Please indicate by raising a hand when you have the image. Shortly afterward, I will ask you if a signal was present. Please report just as before if there was a light, a sound, or nothing. When a signal is present, it will be presented at the same time as you are experiencing the image. But please focus on your image, as it is important that you have a clear impression of the item being imaged.

On each of the 96 trials, *S* raised his hand when he "had" the image requested; and as soon as he raised his hand, either the auditory signal, the visual signal, or no signal was presented. About 5 sec. after he raised his hand, he was asked to report which signal condition he believed to have been present.

Discrimination 2. The session concluded with a second discrimination, similar to the first, but with 33 or 45 trials (omitted in 2 of the 48 sessions and incomplete in 2 others).

The other five sessions followed the same design. The instructions were abbreviated, however: *S*s were told, e.g., "Now we will have the imaging trials."

Images. Ninety-six different images were requested in the imaging session. On each trial, *S* was asked to "imagine seeing a volcano" or "imagine the sound of a typewriter." The images were selected on the basis of their sense modality and also for relative familiarity.

As images of unfamiliar objects may be less distinct, it was predicted that they would be more readily confused with stimuli than familiar images and would have a smaller *d'*. Such a finding could be consistent both with the distraction hypothesis and with the hypothesis that imagery and perception are similar. In the first, third, and fifth sessions, *S*s were asked to image only two items (a tree and a phone ringing) 48 times each in random sequence. As they were instructed always to image the same tree or hear the same phone, these images were "experimentally familiar." In the second, fourth, and sixth sessions, *S*s imaged these 2 experimentally familiar items 16 times each, also 32 familiar common objects, 16 visual and 16 auditory (a table, a dog barking, a car horn), and 32 unfamiliar things, 16 visual and 16 auditory (a dinosaur, an elephant; an oboe), elicited in random order.

Results

Detection of the signal (*d'*) was poorer for imaging than for discrimination, poorer when image and signal were in the same sensory mode, and slightly worse when *S* was imaging unfamiliar objects.

Signal-detection measures are derived from "hit" and "false-alarm" frequencies (cf. Freeman, 1964). As three signal conditions were used rather than the customary two, certain conventions were employed in arriving at these frequencies: to obtain a hit rate, the total number of "hits" divided by number of signals presented was calculated separately for each sensory modality; for the false-alarm rates, the number of false alarms that occurred when there was either no signal or a cross-modal signal was divided by the total number of no-signal trials.

As in previous work (Segal & Fusella, 1969; Segal & Glicksman, 1967; Segal & Gordon, 1969), imagery clearly interfered with detection of the signal (cf. Table 1). In the previous experiments, *S*s had imaged the objects and also given a verbal description of their imagery; in the present experiment, they gave no verbal reports during imagery, but merely imaged the items mentally (assuming that they followed instructions). Nevertheless, sensitivity (*d'*) was again lower during imaging than in either the preceding or following discrimination tasks. This confirmed Perky's (1910) effect once again for visual signals and demonstrated it for the first time with an auditory signal. Using the *G* test to measure significance of difference of two *d'* scores (Gourevitch & Galanter, 1967), *d'* in the imaging tasks differed significantly from *d'* in the comparable discrimination tasks (cf. Table 1). Criterion or likelihood ratio (*Lx*) did not differ significantly between the imaging and discrimination tasks (Wilcoxon sign test).

Within the imaging task, blocking was greater when image and signal were in the same sensory modality. Sensitivity (*d'*) was very acute with the auditory signal, and auditory images reduced this *d'* more than visual images; *d'* values for the visual signal were generally lower, and they were decreased more by imaged pictures than by imaged sounds (cf. Table 1). *Lx* was also lower in the same modality conditions, indicating that more visual false alarms occurred during visual imaging, more auditory false alarms during auditory imaging (Wilcoxon $t = 2.33$, $p < .01$, for the visual signal; *ns* for the auditory signal).

TABLE 1

Frequency of Hits and False Alarms (fa's), d' and Lx Values, in Imaging and Discrimination Tasks: Exp. I

Task	Visual signal			Auditory signal		
	Hits/FA	d'	Lx	Hits/FA	d'	Lx
First discrimination	.73/.094	1.93	1.97	.93/.009	3.84	5.52
Second discrimination	.64/.087	1.72	2.36	.90/.002	4.16	27.68
Visual imaging	.60/.109	1.48	2.06	.87/.006	3.64	12.44
Auditory imaging	.62/.084	1.68	2.47	.82/.013	3.14	7.38

	Visual signal		Auditory signal	
	G	p	G	p
Imaging vs:				
First discrimination	4.21	.001	2.67	.01
Second discrimination	1.53	.06	2.32	.05
Visual vs. auditory imaging	1.79	.025	2.19	.02

When image and signal were in the same modality, unfamiliar images blocked the signal most with the smallest d', while the largest d' was obtained with the two repeated (experimentally familiar) images, the predicted effect ($G = 1.55$, $p = .06$, for the visual signal; G could not be calculated for the auditory signal, as there were so few false alarms). However, the reverse effect was obtained with the cross-modal instances ($p < .10$), and there were no systematic differences between odd sessions (with only experimentally familiar images) and even sessions (with all three types of image).

Experiment II

Method

As there was considerable variability in the data of the first experiment, the experiment was repeated with certain modifications and better controls.

Subjects.—Six male undergraduates, 17 and 18 yr. of age, served as paid volunteer *S*s. They were experimentally naive. Each *S* served for eight 2-hr. sessions and was paid only after completion of all eight sessions.

Apparatus and stimuli.—The visual signal was presented using the same apparatus as in Exp. I, although a different signal was used. This one was a pattern in the shape of a triangle, having three parallel green bars of unequal length, placed with the shortest on top. For the auditory signal, a Beltone audiometer, located in the experimental room, generated a 250-cps pure tone over a small speaker; no earphones were used.[3] Intensity could be finely graded, and onset and offset of the tone were clean.

Procedure.—Each *S* served for eight sessions, and each session had a practice period, an initial discrimination, imaging, and a concluding discrimination. Instructions were similar to those of Exp. I.

Practice. During the preliminary practice period of each session, *E* adjusted intensity of the signals to a point where *S* made about 20% errors. Signals were then maintained at this intensity for the remainder of the session.

Discrimination 1. The *S*'s accuracy in discriminating the two signals was measured over 99 trials, using the same procedure as in Exp. I. However, when *S* reported which signal he believed present, he also gave his level of certainty as "definite," "probably," and "guessing."

Imaging. The 126-trial imaging condition followed. Before the task, *S*s were instructed as follows:

> Next, we are going to ask you to make the same discriminations while you are attending to your mental imagery. Let us pause for a moment to explain what is meant by imagery. Images are mental pictures, usually of things you have seen, sometimes of things you would like to see. Let me ask you now: "How many drawers are there in your bureau?" How did you arrive at the answer? That is what we mean by an image. Probably you have had the same experience when you're trying to remember a specific face or place. Probably you have also had images of sounds, as when you're trying to recall a

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[3] The authors thank R. Guinta, of Clinical and Research Audiometers, for loan of the audiometer.

TABLE 2

FREQUENCY OF HITS AND FALSE ALARMS (FA'S) d' AND Lx VALUES, IN IMAGING AND DISCRIMINATION TASKS: EXP. II

Task	Visual signal			Auditory signal		
	Hits/FA	d'	Lx	Hits/FA	d'	Lx
First discrimination	.82/.042	2.64	2.93	.83/.032	2.81	3.53
Second discrimination	.80/.023	2.84	5.00	.79/.034	2.63	3.82
Visual imaging	.61/.078	1.70	2.63	.67/.037	2.23	4.48
Auditory imaging	.63/.036	2.13	4.78	.61/.067	1.78	2.96

	Visual signal		Auditory signal	
	G	p	G	p
Imaging vs:				
First discrimination	7.70	.001	7.84	.001
Second discrimination	8.76	.001	6.83	.001
Visual vs. auditory imaging	3.94	.001	4.01	.001

melody. To begin with, let me ask you to imagine a tree. Now could you try to imagine hearing a phone ringing?

This was followed by the instructions used in Exp. I: "During the next procedure, you will be asked to imagine various things . . . it is important that you have a clear impression of the item being imaged." Procedure for these imaging trials was similar to the imaging conditions in Exp. I, except S reported his level of certainty in giving his judgments.

Discrimination 2. A second discrimination task of 99 trials concluded each session.

Images. The images were again varied with respect to sense modality and familiarity. Prior to the experiment, a list of 260 images had been rated for familiarity by 20 graduate students. Three lists of 126 images each were prepared from these ratings. Each list contained 42 unfamiliar images, 21 visual and 21 auditory; 42 familiar images, 21 visual and 21 auditory; and also one auditory and one visual image of intermediate familiarity, each repeated 21 times. Order was randomized within each list. As each S had eight sessions, two of the lists were presented three times each and one was given twice to each S.

Results

The data strongly confirmed the findings of the first experiment. Again, d' was lower in the imaging tasks than for discrimination, lower in isomodal than in cross-modal imaging, and clearly lower with more unfamiliar than familiar images. All these effects were stronger and more stable (cf. Table 2).

In Exp. II, intensity of visual and auditory signals had been adjusted so that sensitivity was virtually the same for both. The d' was clearly smaller when image and signal were in the same modality; this was not only obtained with the group data (G test, $p < .001$), but was also obtained for each of the six Ss' individually, with no reversals. The Ss' level of confidence reports were analyzed to permit the plotting of receiver operating characteristic (ROC) curves; shown in Fig. 1, these graphically illustrate the effect.

Likelihood ratio (Lx) again did not differ significantly between the imaging and discrimination tasks; but within the imaging condition, it was again lower in the isomodal conditions due to the larger frequency of false alarms (Wilcoxon $t = 2.10$, $p < .05$, for the visual signal; $t = 1.68$, $.10 > p > .05$, for the auditory signal).

Almost three times as many observations could be used to calculate the effect of familiarity in Exp. II compared to Exp. I, and the data were much more consistent. The d' was again smallest with unfamiliar images, intermediate with familiar images, and largest with the repeated (experimentally familiar) images ($G = 3.95$, $p < .001$, for the visual signal; $G = 2.68$, $p < .01$, for the auditory signal); this effect was obtained when image and signal were in the same and when they were in different sensory modalities. Therefore, familiarity measures were combined, without regard to the sensory mode of the image, to obtain the ROC curves shown in Fig. 2.

DISCUSSION

In the present experiments, mental imagery was found to block detection of both visual and auditory signals. Even though *S*s gave no verbal descriptions, but merely imagined the items mentally, sensitivity (*d′*) was much lower during imaging than during preceding or subsequent discrimination tasks. For the imaging tasks, sensitivity was lower when the image was in the same sensory mode as the signal and likelihood ratio (*Lx*) was lower too. The *S*s apparently confused auditory images with auditory signals, visual images with visual signals; e.g., when *S* was imaging a mental picture, he was significantly more likely to miss a visual signal and also more likely to guess that a visual signal was there when there was either nothing or an auditory signal. All of these effects were more pronounced when *S* was trying to image unfamiliar objects than when he was imaging more practiced or familiar items.

Taken together, these results suggest that attention may play a role, as evidenced by the fact that blocking was demonstrated even with cross-modal imagery. However, they are not consistent with the hypothesis that central attention or distraction is the sole or sufficient explanation of the phenomenon. If a visual image diverts central attention, it should distract equally from both focal tasks of signal detection, regardless of whether the signal is visual or auditory. Instead, the same visual images block visual signals more than auditory signals, and the same visual signals are less detectable when *S* is imaging pictures than sounds.

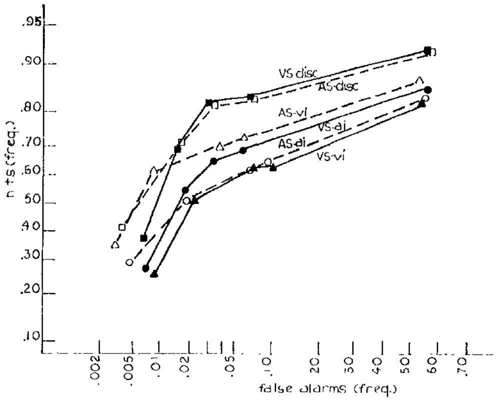

FIG. 1. Experiment II: ROC curves, plotted on double probability paper, comparing detection of visual signals (VS—filled symbols) and auditory signals (AS—open symbols, dashed lines) in the simple discrimination task (disc—squares) with visual imaging (vi—triangles) and with auditory imaging (ai—circles). (Differences between curves represent the *d′*.)

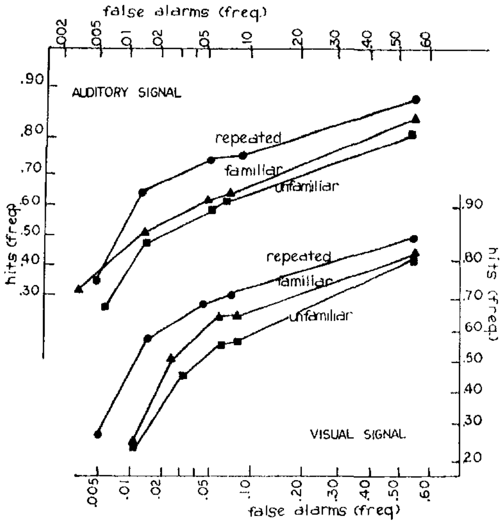

FIG. 2. Experiment II: ROC curves for detection of the auditory signal and the visual signal while imaging unfamiliar, familiar, and repeated images. (Auditory and visual images are combined.)

Some of the present data seem consistent with a model of limited channel capacity (Broadbent, 1958). Thus the image and signal may be separate events competing for channel space; as channel space is in part modality-specific, visual images and signals would use more common channel space than a visual image and an auditory signal. Also, an unfamiliar image might require more channel space than a familiar image and therefore block detection of the signal more. Such an explanation would conform to the findings of Brooks (1967), who reported that a task which depends on spatial imagery interferes more with written responses, while a task that depends on auditory imagery results in less accurate and slower verbal responses. It is not clear, however, how one can integrate with such a model the finding that false alarms tend to be modality-specific.

A slightly different explanation is that imaging represents an internal signal, and the external signal must be discriminated both from this internal signal and from random background noise. This model assumes that both a perception and an image have an internal representation and *S* makes his sensory decision on the basis of these internal representations; when they are very similar or when the imaged signal is very strong, discrimination of the physical signal becomes more difficult. The fact that the physical signal must have an internal representation is well established; and when signal-to-noise ratio is measured with a human, rather than an ideal, receiver, it is generally assumed that reception of the signal shows normal fluctuation just as noise does and that the sensory effect of the signal varies randomly over time (cf. Green & Swets, 1966; Triesman, 1964). The *d′*, or signal-to-noise ratio, represents the difference between the means of the normalized curves for reception of the signal and for reception of the noise. The present data suggest that a third curve may be postulated, corresponding to the sensory effects of the image. It is not yet possible to plot the mathematical function which describes the mental image, but it appears to be related to the difference between the *d′* obtained in the imaging task and the *d′* obtained with the same signal in a simple detection task. When the sensory effects of the image are similar to those of the physical signal, i.e., when they are in the same sensory mode, the three curves are closer and *d′* is reduced. An unfamiliar image, which is subjectively experienced as more effortful, may evoke more sensory activity; thus it would have a stronger internal signal than a highly practiced image, with a higher mean, and again *d′* would be lower. Moreover, when no physical signal is present, but *S* is imaging, the rate of neural firing in the sensory pathways is raised, so there will be more false alarms than in the no-signal trials of the discrimination conditions.

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(Received July 30, 1969)