ervals, are matched to the functions
y perform.

The synaptic mechanisms that deter-
ne the durations of the IPSP's in the
yfish are unknown. However, γ-
inobutyric acid (GABA) is the puta-
e transmitter at two synapses with
P's of long duration [those onto the
tor giant (6, 7) and onto the flexor
scles (24)] and at two synapses with
P's of short duration [those onto the
scle receptor organ (25) and onto the
ensor muscles (24)]. Since these syn-
ses are accessible, it should be pos-
le to distinguish among explanations
sed on different durations of trans-
tter release, transmitter inactivation,
postsynaptic response.

The behavioral significance of PSP du-
ions shown here calls attention to the
portance of PSP durations in neural in-
mation processing and should encour-
e investigations of the mechanisms
t determine the time courses of syn-
ic events.

JEFFREY J. WINE
GRACE HAGIWARA
partment of Psychology,
nford University,
nford, California 94305

**References and Notes**

E. R. Kandel, *Cellular Basis of Behavior* (Free-
man, San Francisco, 1976), pp. 542-575.
F. B. Krasne, *J. Exp. Biol.* **50**, 29 (1969); R. S.
Zucker, D. Kennedy, A. I. Selverston, *Science*
**173**, 645 (1971); R. S. Zucker, *J. Neurophysiol.*
**35**, 599 (1972); *ibid.*, p. 621.
C. A. G. Wiersma, *J. Neurophysiol.* **10**, 23
(1947).
T. J. Carew and E. R. Kandel, *ibid.* **40**, 692
(1977); *ibid.*, p. 708; *ibid.*, p. 721.
J. J. Wine and F. B. Krasne, *J. Exp. Biol.* **56**, 1
(1972).
E. J. Furshpan and D. D. Potter, *J. Physiol.
(London)* **145**, 289 (1959); *ibid.*, p. 326.
R. Ochi, *Pfluegers Arch.* **311**, 131 (1969).
K. Takeda and D. Kennedy, *J. Cell. Comp.
Physiol.* **64**, 165 (1964).
D. Kennedy, *Physiologist* **14**, 5 (1971); A. I. Sel-
verston and M. P. Remler, *J. Neurophysiol.* **35**,
797 (1972); J. E. Mittenthal and J. J. Wine, *Sci-
ence* **179**, 182 (1973).
S. N. Treistman and M. P. Remler, *J. Comp.
Physiol.* **100**, 85 (1975); J. J. Wine and G. Hag-
iwara, *ibid.* **121**, 145 (1977).
J. J. Wine, *ibid.*, p. 173.
D. Kennedy, R. L. Calabrese, J. J. Wine,
*Science* **186**, 451 (1974).
F. B. Krasne and J. S. Bryan, *ibid.* **182**, 582
(1973).
A. M. Roberts, *J. Exp. Biol.* **48**, 545 (1968).
J. J. Wine, *J. Neurophysiol.* **40**, 1078 (1977).
——— and D. Mistick, *ibid.*, p. 904.
S. W. Kuffler and C. Eyzaguirre, *J. Gen.
Physiol.* **39**, 155 (1955).
I. Parnas and H. L. Atwood, *Comp. Biochem.
Physiol.* **18**, 701 (1966).
C. A. G. Wiersma, *J. Cell. Comp. Physiol.*
**40**, 399 (1952); R. O. Eckert, *ibid.* **57**, 163
(1961).
Photography at 250 frames per second was ac-
complished with a Hycam 16 mm camera (Red-
lake Laboratories) and Kodak Ektachrome EFB
449. Film was viewed with a stop-frame projec-
tor; durations were measured from the first de-
tectable movement.
An interesting but, at first sight, confusing fea-
ture of the escape response is that most of the
flexor elements are silent during the actual flex-
ion movement. This is because the flexor motor
discharge is abrupt, ending within about 10 msec
of stimulation, while delays caused by ex-
citation-contraction coupling and by inertia re-
tard the onset of movement. Hence peak veloc-

ity of flexion may occur roughly 20 msec after
stimulation, at a time when all of the neural ele-
ments that triggered the flexion are being inhib-
ited.
22. For details of electrophysiological recordings
see (6, 7, 11, 15, 16). Briefly, 3M KCl or potas-
sium acetate electrodes were placed in cell bod-
ies or muscle fibers; ganglia were desheathed
and the preparations superfused with oxygen-
ated crayfish saline at 14° to 18°C.
23. S. Hagiwara, *J. Gen. Physiol.* **41**, 1119 (1958).
24. It is known that GABA is the inhibitory trans-
mitter at some crustacean neuromuscular syn-
apses; GABA may be the common neuromuscu-
lar inhibitory transmitter in crustacea. For re-
cent reviews see M. Otsuka and A. Takeuchi, in
*GABA in Nervous System Function*, E. Roberts,
T. N. Chase, D. B. Tower, Eds. (Raven, New
York, 1976), pp. 245 and 255.
25. S. W. Kuffler and C. Edwards, *J. Neurophysiol.*
**21**, 589 (1958).
26. D. Mistick, unpublished data.
27. J. J. Wine, unpublished data.
28. This work was supported by grant BNS 75-
17826 from the National Science Foundation.
We thank D. Kennedy and N. Wessells for the
loan of equipment, M. Burrows, D. Kennedy,
I. Parnas, F. Krasne, M. Siegler, P. Getting,
and D. Mistick for criticism, and Cecilia
Bahlman for typing the manuscript.

23 May 1977; revised 12 September 1977

# Pitch Memory: An Advantage for the Left-handed

Abstract. *In an auditory or musical memory task, subjects made pitch recognition
judgments when the tones to be compared were separated by a sequence of inter-
polated tones. The left-handed subjects performed significantly better than the right-
handed and also had a significantly higher variance. Further analysis showed that
the superior performance was attributable largely to the left-handed subjects with
mixed hand preference.*

People who are left-handed differ as a
group from those who are right-handed
and display more heterogeneity, in terms
of both direction and degree of cerebral
dominance. (i) In the overwhelming ma-
jority of the right-handed population,
speech is represented in the left cerebral
hemisphere; however, in about two-
thirds of the left-handed population,
speech is represented in the left hemi-
sphere and in about one-third, in the
right. (ii) Although the right-handed tend
to show a clear-cut dominance of the left
hemisphere for speech, a considerable
proportion of the left-handed have some
speech representation in both cerebral
hemispheres (1).

Interest has developed in the possi-
bility that such neurological differences
might be reflected in differences in vari-
ous abilities. Thus, some investigators
have argued for a relationship between
left-handedness or mixed hand prefer-
ences and reading disability (2). Others
have presented evidence that left-handed

persons or those with mixed hand prefer-
ence perform more poorly than right-
handed persons on visuospatial tasks (3).
In contrast, I now report what is, to my
knowledge, the first evidence for an as-
sociation between left-handedness and
superior auditory or musical processing
ability. The research was prompted by
the observation that among subjects se-
lected for high performance on a pitch
memory task, an unexpectedly high pro-
portion were left-handed. I therefore
planned an experiment to determine
whether the two populations differ statis-
tically in terms of their ability to make
pitch memory judgments.

A test tone was presented and fol-
lowed by a sequence of six interpolated
tones and then by a second test tone.
The test tones were either identical in
pitch or differed by a semitone. The sub-
jects indicated on paper whether the test
tones were the same or different. All
tones were 200 msec in duration and sep-
arated by 300-msec pauses, except that a
2-second pause intervened between the
last interpolated tone and the second test
tone. The tones were sine waves with
frequencies taken from an equal-tem-
pered chromatic scale (International
Pitch; A = 435 hertz) ranging over an
octave from middle C (259 hertz) to the B
above (488 hertz). The interpolated tones
were chosen at random from this range,
except that no interpolated sequence
contained repeated tones or tones that
were identical in pitch to either of the
test tones. Twenty-four sequences were
presented in two groups of 12, with 10-
second pauses between sequences with-
in a group and 2-minute pauses between
the groups. Before the experimental ses-
sion began, the procedure was explained

Table 1. Performance levels of all four hand-
edness populations on the pitch memory task.
Each subgroup was compared with the mod-
erately left-handed subgroup by means of a
median test.

| Group | N | Average error (%) | $\chi^2$ |
|---|---|---|---|
| **Right-handed** | | | |
| Strongly | 52 | 36.9 | 10.02* |
| Moderately | 24 | 41.0 | 9.65* |
| Total | 76 | 38.1 | |
| **Left-handed** | | | |
| Moderately | 23 | 29.0 | |
| Strongly | 30 | 35.3 | 4.45† |
| Total | 53 | 32.5 | |

*$P < .01$.  †$P < .05$.

to the subjects and they were given four practice sequences (4).

The subjects were 76 right-handed and 53 left-handed university undergraduates (5). The average error rates for these two groups are shown in Table 1. The variance of the left-handed group was significantly higher than that of the right-handed group [$P < .05$ (6)]. Further, the left-handed subjects made significantly fewer errors than the right-handed (median test, $\chi^2 = 8.03$, d.f. = 1, $P < .01$) (7). Given the larger variance in the left-handed group, I hypothesized that those who were strongly left-handed might differ from those with a mixed preference, since individuals in the latter group would be expected to have more bilateral representation of function (8). Each population was therefore subdivided on the basis of strength of manual preference (Table 1) (9). There was an overall significant difference among these four subgroups (median test, $\chi^2 = 12.33$, d.f. = 3, $P < .01$). Further, the performance of the left-handers with a mixed preference (moderately left-handed) was significantly more accurate than that of any of the other three groups (Table 1). The other groups did not differ significantly from each other.

These findings suggest an explanation in terms of a duplication of storage of pitch information by the moderately left-handed. If the efficiency of storage and retrieval at one locus is identical for all populations, then the retrieval of this information from two separate loci should significantly increase the overall probability of correct judgment. We can further hypothesize that such duplication of representation occurs in parallel with the duplication of representation of speech functions in the two hemispheres. We cannot, of course, specify whether the pitch information is retained in the dominant or the nondominant hemisphere in the case of people for whom a more completely unilateral storage is hypothesized (10).

It remains to be determined to what extent the superiority of the moderately left-handed on this pitch memory task generalizes to other auditory or musical situations. However, other left-handed subjects selected for previous experiments on the basis of superior performance on such a task performed unusually well on a variety of tests of musical memory, including the transposition of melodic sequences (11).

The finding that the moderately left-handed differ significantly in performance from the moderately right-handed also demonstrates that the "ambi-

dextrous" should not be considered a single population, as is often assumed. Had the two groups been combined in this study, no significant differences would have been seen (12).

DIANA DEUTSCH

*Center for Human Information Processing, University of California, San Diego, La Jolla 92093*

### References and Notes

1. H. Goodglass and F. Quadfasel, *Brain* 77, 521 (1954); H. Hécaen and M. Piercy, *J. Neurol. Neurosurg. Psychiatry* 19, 194 (1956); O. L. Zangwill, *Cerebral Dominance and its Relation to Psychological Function* (Oliver & Boyd, Edinburgh, 1960); H. Hécaen and J. de Ajureaguerra, *Lefthandedness* (Grune & Stratton, New York, 1964); B. Milner, C. Branch, T. Rasmussen, *Trans. Am. Neurol. Assoc.* 91, 306 (1966); P. J. Vinhen and G. W. Bruyn, Eds., *Handbook of Clinical Neurology* (North-Holland, Amsterdam, 1969), vol. 4.
2. E. Shearer, *Educ. Res.* 10, 197 (1968); R. M. Wold, *J. Am. Optom. Assoc.* 39, 908 (1968); M. Wussler and A. Barclay, *Percept. Mot. Skills* 31, 419 (1970); G. P. Ginsburg and A. Hartwick, *ibid.* 32, 535 (1971); E. B. Zurif and E. Carson, *Neuropsychologia* 8, 351 (1970); P. Satz and S. S. Sparrow, in *Specific Reading Disability*, D. J. Bakker and P. Satz, Eds. (Rotterdam Univ. Press, Rotterdam, 1970). But see also A. A. Applebee, *J. Child Psychiatry* 12, 91 (1971); L. C. Hartlage and J. B. Green, *Percept. Motor Skills* 32, 133 (1971).
3. J. Levy, *Nature (London)* 224, 614 (1969); E. Miller, *Br. J. Psychol.* 62, 111 (1971); A. Silverman, G. Adevai, W. McGough, *J. Psychosom. Res.* 10, 151 (1966). But see also F. Newcombe and G. Ratliff, *Neuropsychologia* 11, 379 (1973).
4. The tones were produced at equal amplitude by an oscillator (Wavetek) controlled by a PDP-8 computer, and were recorded on tape. They were played to subjects through speakers on a tape recorder (Revox).
5. Handedness was assessed by the short form of the Edinburgh Handedness Inventory [R. C. Oldfield, *Neuropsychologia* 9, 97 (1971)]. The
6. B. J. Winer, *Statistical Principles in Experimental Design* (McGraw-Hill, New York, 1
7. No significant differences based on sex tained.
8. S. M. Gillies, D. A. MacSweeney, O. will, *Q. J. Exp. Psychol.* 12, 113 (1960) caen and J. Sauget, *Cortex* 7, 19 (197 Dimond and J. G. Beaumont, Eds., *Het Function and the Human Brain* (Wile York, 1974).
9. The strongly right-handed were defined with laterality quotients between +60 a the moderately right-handed, those w tients between +1 and +59; the stro handed, those with quotients between −100; and the moderately left-hande with quotients between −1 and −59.
10. M. Critchley and R. A. Henson, Eds., *M the Brain* (Heinemann, London, 1977).
11. D. Deutsch, unpublished observations.
12. The present criterion for dividing popula to right-handed and left-handed groups c highly with hand used in writing. The population in this experiment would I little pressure on them to write with hand, in contrast to subjects of earlier s those of older patient populations. Th tance of the hand used in writing as a for dividing populations accords well conclusions of M. Annett [*Br. J. Psy* 303 (1970)]. In a study by B. Bryne [*Bi chol.* 65, 279 (1974)], a variant of the tonal memory test was used to compar formance of the strongly right-hand those of mixed hand preference (take group), and no effect of handedness w: However, I would have found no effe had the handedness populations been d this way.
13. Supported by PHS grant MH-21001. S. Hickey for his assistance in data c and J. Miller and W. Wickelgren for discussions.

16 May 1977; revised 22 August 1977

# Dextroamphetamine: Cognitive and Behavioral Effects in Normal Prepubertal Boys

Abstract. *The behavioral, cognitive, and electrophysiological effects of a dose of dextroamphetamine (0.5 milligram per kilogram of body weight) or p was examined in 14 normal prepubertal boys (mean age, 10 years 11 month double-blind study. When amphetamine was given, the group showed a marl crease in motor activity and reaction time and improved performance on co tests. The similarity of the response observed in normal children to that repo children with "hyperactivity" or minimal brain dysfunction casts doubt o1 physiological models of minimal brain dysfunction which assume that childr* this syndrome have a clinically specific or "paradoxical" response to stimu:*

Considerable clinical experience indicates that the behavioral response of increased alertness and focused activity of children with "hyperactivity" or minimal brain dysfunction (MBD) given stimulant drugs is nonparadoxical with regard to adult response, and nonspecific in comparison to other pediatric populations. Clinical nonspecificity is suggested by the fact that children selected for treatment on the basis of teacher recommendation alone (1), delinquent behavior without documented motor rest-

lessness or attentional deficit learning disorder without associa havioral disturbance (3) all show i imately the same short-term in ment on cognitive test perform show decrease in restless-impuls haviors when given stimulant r tion. Moreover, the increased al and arousal, as measured by cha reaction time and performance o1 tive tests, are similar to those r for normal adults given com doses of stimulant drugs (4); in a