results. Thus, "perhaps" is listed in Table 1 for mutual inhibition to indicate dimensions for which evidence consistent with inhibition has been observed in near-threshold psychophysical experiments.

CONCLUSION

The many hundreds of near-threshold psychophysical studies of pattern vision published in the past three decades form an impressive and compelling body of evidence for a model in which a fundamental process is the breaking down of the visual stimulus by a set of multiple analyzers, acting in parallel, with different ranges of sensitivity along different dimensions. Considered together, these studies and the neurophysiological studies of the same period suggest that the physiological substrate of the multiple analyzers is area V1 (the lowest level of cortical visual processing) and perhaps area V2.

As is consistent with this presumed physiological substrate, these multiple analyzers are apparently at a relatively low level in the full stream of visual processing (although coming after a number of other processes, e.g., light adaptation). It seems clear that much complicated computation intervenes between the analyzers' outputs and observers' perceptions.

In the past three decades, we have learned much about how our visual systems analyze the proximal visual stimulus into parts. A major challenge for the future is to find out how the parts that result from this analysis are "put back together" into a perception that generally corresponds very well to the distal stimulus—the arrangement of objects that the perceiver must know about and interact with in order to survive, the "what is where." In trying to take this step forward, we can build on the precise quantitative knowledge about the multiple analyzers that we have gained over the past three decades from both physiology and psychophysics, particularly from near-threshold psychophysics.

Notes

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Gender Differences in Abilities and Preferences Among the Gifted: Implications for the Math-Science Pipeline

David Lubinski and Camilla Persson Benbow

Just over 20 years ago, Julian C. Stanley launched the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University. This study was designed to identify gifted youth who reasoned exceptionally well mathematically and to provide them with better opportunities to develop their already exceptional quantitative skills.

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SMPY identified gifted seventh and eighth graders using the College Board Scholastic Aptitude Test (SAT), which is designed to assess quantitative and verbal reasoning in college-bound high school students. Students scoring in the top 2% to 3% on conventional ability tests (administered in their schools) were invited to take the SAT and, surprisingly, generated score distributions indistinguishable from those for the average high school group. Those seventh and eighth graders with exceptional SAT scores, high enough to suggest intellectual readiness for certain college courses, were invited to try this form of acceleration (as well as others), if they so desired. The results have been nothing short of spectacular. Reviews of the remarkable accomplishments of these gifted youth are readily available.[1] Moreover, programs are now in place across the country for both mathematically and verbally gifted youth.

The purpose of this review is to document some gender differences among the gifted, which have remained pronounced for at least the past 20 years.[2] We focus primarily on those that contribute to achievement and career excellence in math and science disciplines, given recent reports that project critical needs in these areas.[3] Gender differences in mathematical reasoning are noted in particular, but other attributes, cognitive and noncognitive (e.g., interests and values), also are reviewed in the context of theoretical discussions attempting to explain them.

OBSERVED GENDER DIFFERENCES IN ABILITIES

In normative samples, recent studies on gender differences in cognitive functioning have reported that males and females are converging toward a common mean on a variety of abilities, including mathematical reasoning. The most noteworthy studies are the meta-analytic reviews,[4] which have shown that male–female differences are decreasing. Feingold,[5] moreover, studied scores on two test batteries over a 30-year period and also concluded that females have been catching up with males. Although encouraging, these findings are difficult to interpret because of recurring changes in cognitive tests: Stanley[6] has noted that, for at least the past 20 years, some test publishers probably have tried to minimize what some people call "gender bias" by discarding, from one revision to the next, items that show the greatest gender disparities. Moreover, not all studies have documented a decline in gender differences.[6]

Data from 86 nationally standardized achievement and aptitude tests (obtained from 1982 through 1987) reveal important gender differences in specific tests across normative and highly select samples.[6] On the Differential Aptitude Test (DAT), 12th graders display marked gender differences favoring females in spelling (male–female effect size $= -.50$) and males in mechanical reasoning (male–female effect size $= .89$). In more select samples, gender differences also are observed on Advanced Placement and Advanced Graduate Record Examinations, as well as other advanced tests. There is a strong tendency for scores of males to exceed those of females on tests taken mainly by males, but not on tests taken primarily by females.[6] Males tend especially to excel in physics, political science, European history, computer science, and chemistry, among other areas, whereas females are superior to males in English and the foreign languages. The pattern of differences is consistent across many kinds of tests and grade levels, large enough to have a substantial effect on admission to selective universities, and was stable from 1982 to 1987. Are gender differences really decreasing in selective samples? It is difficult to determine.

Consumers of meta-analytic reviews should note that this methodology assesses only group differences in *overall level*. It does not assess ability-dispersion and its effects on extreme cutting scores. Males tend to be more variable on measures of cognitive functioning, even on tests for which females have higher means.[6] As noted earlier, on the spelling portion of the DAT, females score on the average .50 standard deviations above males (i.e., only about 30% of males score above the female mean). Nevertheless, because of greater male variability, the male/female ratio of 3/5 at the female mean increases across more select levels and reaches 1/1 at the 99th percentile. That is, on gender-mixed or combined distributions of "spelling talent," there are approximately equal numbers of males and females in the top 1%.

GENDER DIFFERENCES AMONG THE GIFTED

In mathematically gifted samples, disparate male/female proportions are well-known. They may have resulted from normative differences in level or dispersion or from both operating in concert to produce a collective effect that can be startling. We illustrate this point using data collected over the 20-year period from 1972 through 1991, on well over 1 million seventh (and some eighth) graders who were tested with the SAT-Mathematics (SAT-M) in various talent searches across this country (e.g., Duke, Iowa State, Johns Hopkins, Northwestern, and University of Denver). The seventh graders who qualified for and participated in the testing (approximately equal numbers of males and females) produced gender differences in both level and dispersion of SAT-M scores. The resulting proportion of males to females at various cutting scores on the SAT-M was approximately as follows: SAT-M $\geqslant$ 500, 2/1; SAT-M $\geqslant$ 600, 4/1; and SAT-M $\geqslant$ 700, 13/1.[2,7] The effect of these disparate ratios for the math-science pipeline is clear: A greater number of males than females will qualify for advanced training in disciplines that place a premium on mathematical reasoning.

Other Abilities and Preferences

The picture intensifies when other cognitive and noncognitive gender differences are examined. Table 1 contains data on abilities and values of gifted students tested through SMPY at Iowa State University from 1988 through 1991. Gender differences in mathematical reasoning ability are consistently observed, paralleling findings in other parts of the country.[2] Table 1 also includes other cognitive measures (e.g., of mechanical reasoning and spatial ability). Although no meaningful differences are observed in SAT-Verbal (SAT-V) or Advanced Raven scores, there are substantial gender differences in spatial and mechanical reasoning abilities. These data have further implications for the math-science pipeline. Although mechanical reasoning and spatial abilities typically are not assessed when selecting individuals for advanced training in basic science, strong abilities in these areas are salient characteristics of physical scientists.[8]

Abilities are only one important class of variables that affect career decisions; values are another. Two especially important values in Table 1 deserve particular attention. Intense *theoretical values* are characteristic of physical scientists and are also more characteristic of males than females. *Social values* are negatively correlated with interests in physical science and are more characteristic of females than males. These differences in values are not anything new. What we in essence are describing here are gender differences related to one of the most celebrated dimensions of individual differences, "people versus things" (females tend to gravitate toward the former; males, to the latter). These gender differences were in existence —and pronounced—long before Thorndike[9] discussed them in his 1911 essay *Individuality*.

Our reason for detailing these gender differences in preferences and abilities is that although students are not formally selected for advanced scientific training based on their theoretical values or their spatial and mechanical reasoning abilities, students self-select based on

Table 1. *Ability and values profiles of mathematically gifted students attending a summer academic program, 1988–1991*

Year and gender	SAT					Advanced Raven's			Mental Rotation			Bennett Mechanical Comprehension			Study of Values												
	N	SAT-M $\bar{X}$	SAT-M SD	SAT-V $\bar{X}$	SAT-V SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	Theoretical $\bar{X}$	Theoretical SD	Social $\bar{X}$	Social SD	Economic $\bar{X}$	Economic SD	Aesthetic $\bar{X}$	Aesthetic SD	Political $\bar{X}$	Political SD	Religious $\bar{X}$	Religious SD
1991																											
● Males	68	532	101	426	78	68	25.1	3.9	68	29.9	8.1				68	47.7	7.0	37.1	7.3	41.6	7.2	36.4	8.2	42.9	6.6	34.2	10.4
● Females	51	480	87	418	87	51	25.8	4.3	51	25.1	10.2				51	42.0	6.8	43.2	8.1	37.8	6.9	42.6	7.1	39.0	7.2	35.4	10.2
■ Males	107	579	101	413	81	92	25.2	4.2	95	30.0	8.1				77	47.6	6.9	37.1	7.0	41.8	6.9	36.5	8.3	43.1	6.8	33.8	10.1
■ Females	67	472	85	418	80	58	25.9	4.2	63	24.1	10.0				57	41.7	7.0	43.8	8.3	37.5	7.0	42.8	7.5	38.7	7.0	35.6	10.3
1990																											
● Males	69	537	100	415	79	69	24.5	6.5	69	29.2	9.1				69	46.6	8.8	38.4	7.8	40.4	8.2	38.4	8.4	42.5	6.9	33.4	11.4
● Females	48	487	74	422	76	48	25.3	4.4	48	22.5	9.7				48	40.3	8.0	44.0	8.0	35.8	7.1	42.1	6.4	40.1	6.7	37.5	8.1
■ Males	87	545	96	415	79	82	24.6	6.8	80	29.8	8.8				73	46.6	8.7	38.3	7.6	40.4	8.1	37.8	8.7	42.7	6.8	33.9	11.3
■ Females	61	487	71	419	80	57	25.1	4.1	56	21.6	9.4				51	40.7	8.0	43.6	8.1	35.3	7.2	42.8	7.1	40.1	6.6	37.1	8.4
1989																											
● Males	20	585	86	441	98	20	27.3	4.4	20	24.9	9.9	20	40.2	9.4	20	49.3	7.4	35.4	5.9	40.3	9.4	37.3	8.0	45.0	7.8	30.8	11.1
● Females	11	505	80	449	96	11	24.7	5.1	11	17.8	4.1	11	35.6	8.0	11	39.0	9.1	42.3	9.1	41.1	9.6	40.6	5.2	40.4	9.3	36.6	12.5
■ Males	43	593	95	446	78	21	27.0	4.4	40	23.8	9.7	42	42.2	10.0	43	50.0	6.8	34.8	7.5	42.2	8.2	37.0	7.7	44.1	8.2	30.9	10.7
■ Females	34	514	82	455	79	11	24.7	5.1	34	21.8	7.9	32	35.2	9.4	34	41.8	7.4	41.2	8.3	39.6	7.7	43.9	8.2	39.2	7.2	34.3	10.9
1988																											
● Males	57	562	81	435	59	57	26.6	3.8							57	48.0	8.5	34.4	7.8	44.9	7.6	35.3	8.1	45.2	8.2	32.4	12.8
● Females	32	491	65	424	80	32	25.1	5.3							32	42.3	7.5	40.7	8.0	38.2	7.5	43.6	8.4	40.1	6.2	34.9	10.3
■ Males	72	571	85	440	62	66	26.8	3.7				8	39.3	6.5	61	48.3	8.5	34.5	7.6	44.7	7.4	35.0	8.0	44.8	8.3	32.9	12.7
■ Females	39	500	64	425	76	36	25.3	5.3				9	29.0	7.2	33	42.5	7.4	40.9	8.0	38.0	7.5	43.4	8.4	40.0	6.2	35.2	10.2

● Students who took all the tests; ■ Students who took at least one test.

Note. All participants were identified by a talent search by age 13 and subsequently enrolled in a summer academic program for the gifted at Iowa State University (ISU). Students qualified for this program if, as seventh graders, they earned scores of at least 500 on the mathematics SAT (SAT-M) or 430 on the verbal SAT (SAT-V). Only students with SAT-M $\geqslant$ 350 (roughly the top 2% in mathematical reasoning ability) are included here. (Note that the group of students who took all the tests is also included in the group who took at least one test.) ISU's Talent Search is particularly noteworthy because it has the highest participation rate in the nation (more than 75% of all eligible students) and the highest ability scores. Students in these programs tend to be (personally) motivated and (family) supported: Except for limited-income families, parents pay for them to attend. Tests: College Board Scholastic Aptitude Test (mathematics = SAT-M, verbal = SAT-V; for participants beyond seventh grade, SAT scores were adjusted downward 4 points/month); Raven's Progressive Matrices (Advanced); Vandenberg Test of Mental Rotations; Bennett Mechanical Comprehension Test (Form AA); Allport, Vernon, and Lindzey Study of Values. A blank means that a test was not given to the indicated group.

these abilities and preferences,[8] exacerbating the problem of gender representation in technical disciplines. That is, gender differences in mathematical reasoning are compounded by gender differences in three-dimensional spatial visualization and in values critical for a commitment to math and science disciplines.

Educational and Vocational Decision Making and Adjustment

These findings can be organized by a model from vocational psychology. Vocational psychologists have long stressed the importance of at least two sets of attributes for educational and career adjustment and choice: abilities and preferences. Dawis and Lofquist,[10] for example, wrote about *satisfactoriness* (the extent to which abilities correspond to the ability requirements of a given occupation) and *satisfaction* (correspondence between needs, interests, and values and the rewards offered by the discipline or occupation). Both dimensions of correspondence are critical for analyzing educational and vocational adjustment, because all occupations require multiple abilities and provide different reinforcers. A large body of data suggests that mechanical and spatial abilities have special importance for satisfactoriness in engineering and the physical sciences; investigative-theoretical interests and values are important for personal satisfaction in these disciplines.[1,8] Thus, males, compared with females, tend to have ability and preference profiles more congruent with optimal adjustment in math and science careers. As a result, one would expect more males than females in such careers. Next, we reveal how these predictions are borne out.

Longitudinal Data

The data in Table 2 show the gender discrepancy in math and science educational credentials for a sample of males and females in the top 1% of mathematical ability. Clearly, even females who have greater general intellectual ability and quantitative ability than the typical physical scientist are not entering the math-science pipeline in numbers comparable to their male peers. Less than 1% of females in the top 1% of mathematical ability are pursuing doctorates in mathematics, engineering, or physical science. Eight times as many similarly gifted males are doing so.

EXPLANATIONS OF GENDER DIFFERENCES IN ABILITIES AND PREFERENCES

In most treatments of causes for gender differences in abilities, interests, and values, socialization hypotheses have been emphasized.[11] But there are a number of findings that appear to us curious if purported social influences are operating, ex-

Table 2. *Percentages of level of educational attainment or pursuit for mathematically talented students identified by a SMPY talent search*

	Highest degree							
	Bachelor		Advanced (below doctorate)		Doctorate		Total	
Major	Males	Females	Males	Females	Males	Females	Males	Females
Math and science								
Math	3.4	3.5	0.3	0.7	0.5	0.0	4.2	4.2
Engineering	16.2	7.6	7.9	3.0	3.4	0.7	27.5	11.3
Physical science	2.2	1.5	0.5	0.4	3.7	0.2	6.4	2.1
Biology	2.2	5.4	0.3	0.4	1.1	1.5	3.6	7.3
Medicine					8.7	5.9	8.7	5.9
Social science	4.8	6.1	0.4	2.0	1.9	0.9	7.1	9.0
Humanities	2.5	5.0	0.1	2.4	0.8	1.7	3.4	9.1
Law					6.4	4.1	6.4	4.1
Business	7.1	11.1	4.5	5.0	0.8	0.7	12.4	16.8
Total								
All majors[a]	42	52	15	17	28	17	85	86
Math and science	24	18	9	5	18	9	51	32

Note. The students in the sample (N = 786 males, 461 females) were identified by a talent search requiring junior-high math achievement scores in the top 2% and had earned scores of at least 390 on the mathematics SAT or 370 on the verbal SAT when in the seventh or eighth grade (years 1972–1974). The students were surveyed 10 years later (i.e., at age 23). The two bottom rows are rounded to the first whole number. The bracketed cells reveal the low rate at which mathematically gifted females pursue doctorates in mathematics or physical science. Samples defined at this level of mathematical reasoning have special significance for the math-science pipeline because these students earn degrees in math and science at 10 times the national rate.
[a] Includes low-frequency majors not reported above.

clusively, to attenuate in females the development of key attributes associated with satisfaction and satisfactoriness in mathematics and the physical sciences. For example, females tend to get better grades than males in math courses, and they are superior to males on tests of arithmetic computation. Some hypotheses concern sex role identification, yet spatially, mathematically, and verbally gifted adolescents are all less gender stereotyped in nonacademic interests than are their peers.[12] That is, adolescents who excel in cognitive functioning of all kinds do not appear to reject behavioral domains more typical of the opposite sex, nor do they intensely embrace the normative standards most characteristic of their own sex. Finally, a recent meta-analysis of the literature on parents' differential socialization of boys and girls found insignificant effect sizes for a number of abilities and social behaviors.[13] But even if differential socialization experiences result in gender differences, this would not directly address gender differences in ability-dispersion. Why, for example, are males more variable even on traits for which females are superior?

THEORETICAL AND SOCIAL IMPLICATIONS

Theorists must assimilate the multidimensional nature of gender differences when testing hypotheses and especially when speculating on intervention.[14] For example, some have suggested that more females would enter the math-science pipeline if they were required to take more math and science courses in high school. This is an interesting hypothesis, worthy of additional attention. Indeed, we have data consistent with this view: Number of high school math and science courses is related to entering the math-science pipeline, regardless of gender, and females enroll in fewer math and science courses in high school than males. For the most able students, however, relevant ability and preference profiles are in place *before* high school. Investigators need to determine the extent to which these factors operate to determine course selection in high school students. It also would be interesting to ascertain whether courses taken change ability and preference profiles. Would requiring mathematically gifted girls with intense social values to take more math courses in high school increase their representation in the math-science pipeline? Would requiring mathematically gifted boys with intense theoretical values to take more high school courses in English increase their representation in the humanities?

As educational barriers have been removed, an increasing number of women have entered math and science domains, as predicted by Vernon's research on the successful performance of female engineers.[15] Among the mathematically talented, however, more males than females choose and prefer math and science domains, partly because of their abilities, but mostly because of their preferences. Gifted females in many of our studies average beyond the top 1% in mathematical reasoning and clearly have the ability to succeed with distinction in math and science. Yet the majority have stronger competing interests in other areas. Over the past 4 years at Iowa State University, for example, females in programs for the gifted enrolled in math and science courses and English and foreign language courses in essentially equal proportions, whereas males were approximately six times more likely to enroll in math and science areas than in English and foreign language.

In programs for the gifted, females quickly develop impressively sophisticated skills in *whatever* courses they select, as one would anticipate from their test scores. Moreover, mathematically talented females certainly appear to be well aware of their ability to achieve in math and science areas. They self-report it, and counselors and instructors also tell them about the full spectrum of their abilities and their educational and career possibilities. They simply choose to develop their abilities in other areas, unlike the males, who are also told about the breadth and depth of their abilities, but more typically choose math-science tracks. Regardless of the causes of gender differences in abilities and preferences, the stability of these attributes (although not rigidly fixed by age 18) is sufficient to warrant close scrutiny.

An interesting question arises: Would insisting on equal representation in the math-science pipeline impose a "modern" constraint on both genders, motivated by a contemporary ideology that is as psychologically constraining as the earlier unenlightened, male-dominated status quo? Herein may lie an intriguing confrontation between the popular contemporary position of equal representation (or nearly so) in all disciplines and the individualized goals of most career-vocational counselors, who stress the importance of both abilities and expressed preferences (i.e., satisfactoriness and satisfaction) when advising clients in making career decisions. In our culture at this juncture, the personal attributes of males and females are such that, for educational and career decisions, stressing either abilities or preferences will undoubtedly result in disparate male/female proportions in many disciplines; stressing both abilities and preferences will intensify these disparities.

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Notes

1. Investigators associated with SMPY have reported their findings in several books published by Johns Hopkins University Press (Baltimore, MD): J.C. Stanley, D.P. Keating, and L.H. Fox, Eds., *Mathematical Talent: Discovery, Description, and Development* (1974); D.P. Keating, Ed., *Intellectual Talent: Research and Development* (1976); J.C. Stanley, W.C. George, and C.H. Solano, Eds., *The Gifted and the Creative: A Fifty Year Perspective* (1977); L.H. Fox, L. Brody, and D. Tobin, Eds., *Women and the Mathematical Mystique* (1980); and C.P. Benbow and J.C. Stanley, Eds., *Academic Precocity: Aspects of Its Development* (1983). Also, see C.P. Benbow and O. Arjmand, Predictors of high academic achievement in mathematics and science by mathematically talented students, *Journal of Educational Psychology, 82,* 430–441 (1990).

2. C.P. Benbow, Sex differences in mathematical reasoning ability in intellectually talented preadolescents: Their nature, effects, and possible causes, *Behavioral and Brain Sciences, 11,* 169–183, 217–232 (1988).

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7. In American samples, these ratios have been fluctuating over the past decade at least partly as a function of increasing numbers of Asian students entering talent searches. For example, in Asian samples, the proportion of males/females with SAT-M $\geq$ 700 is 4/1 (this ratio also has been observed in China); in Caucasian samples, the ratio is closer to 16/1. Indeed, in SMPY talent searches, approximately 52% of the females scoring at least 700 on the SAT-M by age 13 have been Asian; see A.E. Lupkowski and J.C. Stanley, *Comparing Asians and non-Asians who reason extremely well mathematically,* paper presented at the Cornell Symposium on Asian Americans, Ithaca, NY (May 1988).

8. L.G. Humphreys, Commentary, *Journal of Vocational Behavior, 29,* 421–437 (1986); L.G. Humphreys, T.C. Davey, and E.S. Kashima, Experimental measures of cognitive privilege/deprivation and some of their correlates, *Intelligence, 10,* 355–376 (1986); L.G. Humphreys, D. Lubinski, and G. Yao, *The significance of spatial visualization for becoming an engineer, physical scientist, or creative artist,* manuscript submitted for publication (1991); I.M. Smith, *Spatial Ability: Its Educational and Social Significance* (Knapp, San Diego, 1964); P.E. Vernon, *The Structure of Human Abilities,* 2nd ed. (Methune, London, 1961); G.W. Allport, P.I. Vernon, and G. Lindzey, *Manual: Study of Values* (Houghton-Mifflin, Boston, 1970).

9. E.L. Thorndike, *Individuality* (Riverside Press, Cambridge, MA, 1911).

10. R.V. Dawis and L.H. Lofquist, *A Psychological Theory of Work Adjustment: An Individual Differences Model and Its Application* (University of Minnesota Press, Minneapolis, 1984).

11. Some theorists may be drawn to explanations stemming from socialization because of the erroneous conclusion that if gender differences are environmentally determined, they are somehow more readily modifiable. Whether individual differences in a behavioral trait are primarily determined by biological or environmental factors is not what determines how responsive the differences will be to environmental intervention. Environmentally determined individual differences may be highly resistant to change, and biologically determined individual differences often are quite modifiable. See P.E. Meehl, Specific genetic etiology, psychodynamics, and therapeutic nihilism, *International Journal of Mental Health, 1,* 10–27 (1972).

12. Lubinski and Humphreys, note 6. These investigators also found, for gender-differentiating academic interests, that mathematically gifted males were intensely interested in the physical sciences, and mathematically gifted females were intensely interested in literature. Mathematically gifted males were about as interested in literature as the average female, and mathematically gifted females were about as interested in physical science as the average male.

13. H. Lytton and D.M. Romney, Parents' differential socialization of boys and girls: A meta-analysis, *Psychological Bulletin, 109,* 267–296 (1991).

14. There is a rule in philosophy of science that requires the assimilation of *all* relevant information when evaluating the extent to which a scientific formulation has been confirmed: *the requirement of total evidence.* It was expressed as follows by R. Carnap, in *Logical Foundations of Probability* (University of Chicago Press, Chicago, 1950): "In the application of inductive logic to a given knowledge situation, the total evidence available must be taken as a basis for determining the degree of confirmation" (p. 211). According to P.E. Meehl (personal communication, September 1991), this is the most ignored rule of inference among social scientists.

15. Vernon, note 8.

Hierarchical Associative Relations in Pavlovian Conditioning and Instrumental Training

Robert A. Rescorla

Two elementary forms of associative learning have been extensively studied with animal subjects: Pavlovian conditioning and instrumental training. We now have an excellent understanding of the basic associations formed in those paradigms. A good deal of evidence makes it clear that Pavlovian conditioning results in the formation of a binary association between the conditioned stimulus (CS) and some representation of the unconditioned stimulus (US). Similarly, there is excellent evidence that each of the three primary elements in instrumental training, response (R), outcome or reinforcer (O), and stimulus (S), enters a binary association with each of the other two.

However, recent evidence suggests that the concept of binary associations fails to capture the full richness of even these elementary learning processes. Instead, more hierarchical structures seem to form, so that a stimulus may come not simply to activate a representation of another event, but to modulate the state of an association between two other events. In what follows, I illustrate this point for both Pavlovian conditioning and instrumental training.

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