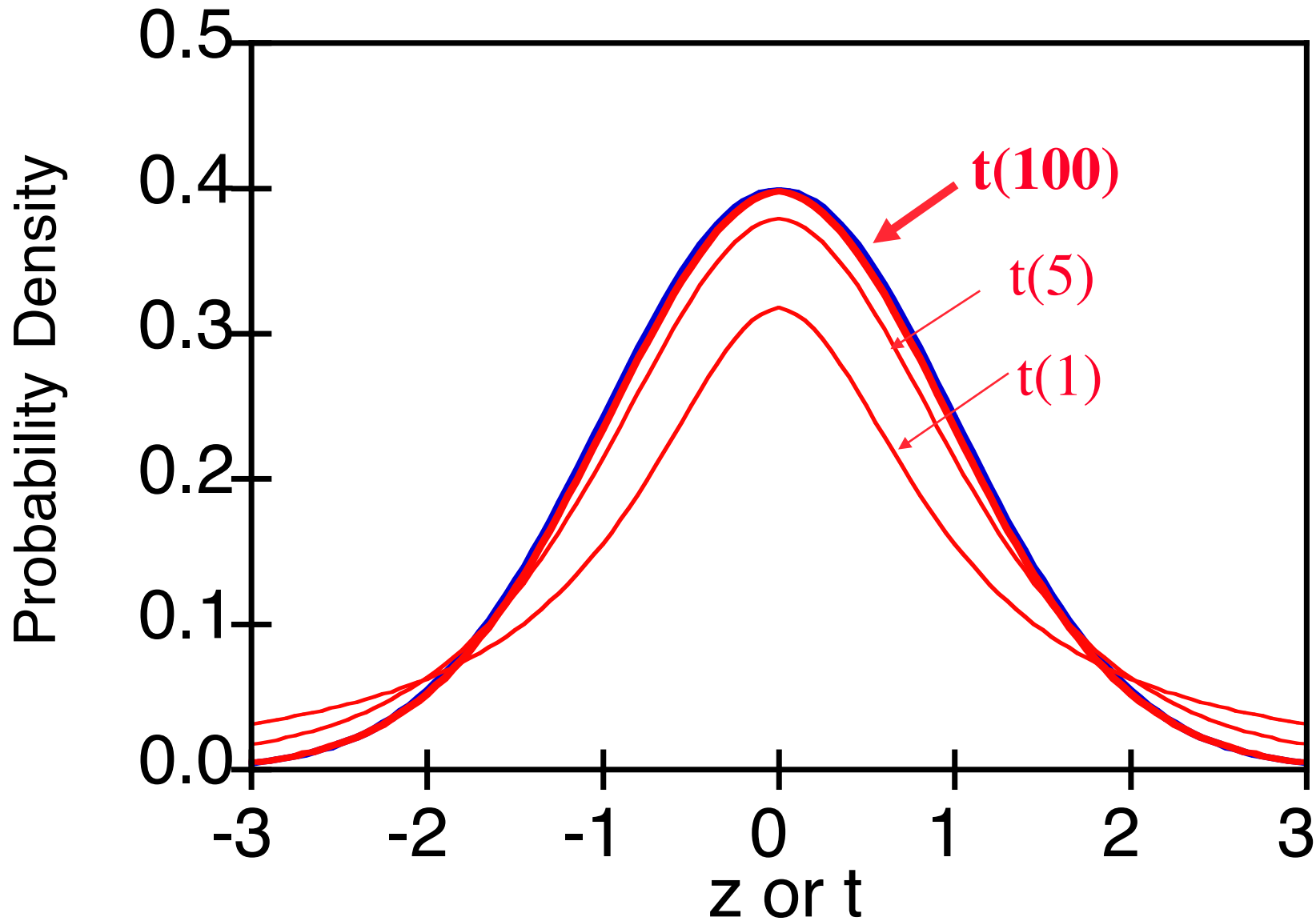


TS Temperature Data:

Person	x = temperature
1	$x_1 = 100.9$
2	$x_2 = 100.0$
3	$x_3 = 100.1$
4	$x_4 = 98.1$
5	$x_5 = 99.9$
6	$x_6 = 99.5$
Mean	$M = 99.750$
Variance	$S^2 = 0.719$
SD	$S = 0.848$

Examples of various t-distributions:



Tables of the t-distribution

e.g., Text, p. 611:

Table E-3 Upper Percentage Points of t Distribution

df	Q = 0.4 2Q = 0.8	...	0.05 0.1	0.025 0.05	...	0.001 0.002
1	0.325	...	6.314	12.704	...	318.31
2	0.289	...	2.920	4.303	...	22.326
⋮	⋮	...	⋮	⋮	...	⋮
5	0.267	...	2.015	2.571	...	5.893
⋮	⋮	...	⋮	⋮	...	⋮
∞	0.253	...	1.645	1.960	...	3.090

Results of the Incentive Experiment (WSD)

Person	Number of Words Recalled		x = (x ₂ - x ₁)
	x ₁ (Low Incentive)	x ₂ (High Incentive)	
1	13	16	3
2	21	27	6
3	10	13	3
4	5	12	7
5	15	14	-1
6	22	21	-1
7	11	15	4
8	7	13	6
9	11	10	-1
10	21	26	5
Means	M ₁ = 13.6	M ₂ = 16.7	M ₂₋₁ = 3.1
estσ =	6.02	5.93	3.11

Results of the Incentive Experiment (BSD)

Number of words recalled

Low Incentive		High Incentive	
$x_{11} =$	11	$x_{12} =$	15
$x_{21} =$	7	$x_{22} =$	13
$x_{31} =$	12	$x_{32} =$	16
$x_{41} =$	9	$x_{42} =$	12
$x_{51} =$	10	$x_{52} =$	16
$x_{61} =$	13	$x_{62} =$	12
$x_{71} =$	9	$x_{72} =$	14
$x_{81} =$	11	$x_{82} =$	7
$T_1 =$	82	$T_2 =$	105
$n_1 =$	8	$n_2 =$	8
$M_1 =$	10.250	$M_2 =$	13.125
$(M_2 - M_1) = 2.875$			

Results of Rotated-Maze Experiment

Number of trials to relearning

Control		Rotated
x ₁₁ = 11	}	x ₁₂ = 14
x ₂₁ = 5	}	x ₂₂ = 11
x ₃₁ = 11	}	x ₃₂ = 13
x ₄₁ = 8	}	x ₄₂ = 10
x ₅₁ = 9	}	
x ₆₁ = 8	}	
x ₇₁ = 7	}	
x ₈₁ = 13	}	
T ₁ = 72		T ₂ = 48
n ₁ = 8		n ₂ = 4
M ₁ = 9.0		M ₂ = 12.0

σ²

σ²

$$(M_2 - M_1) = 3.0$$

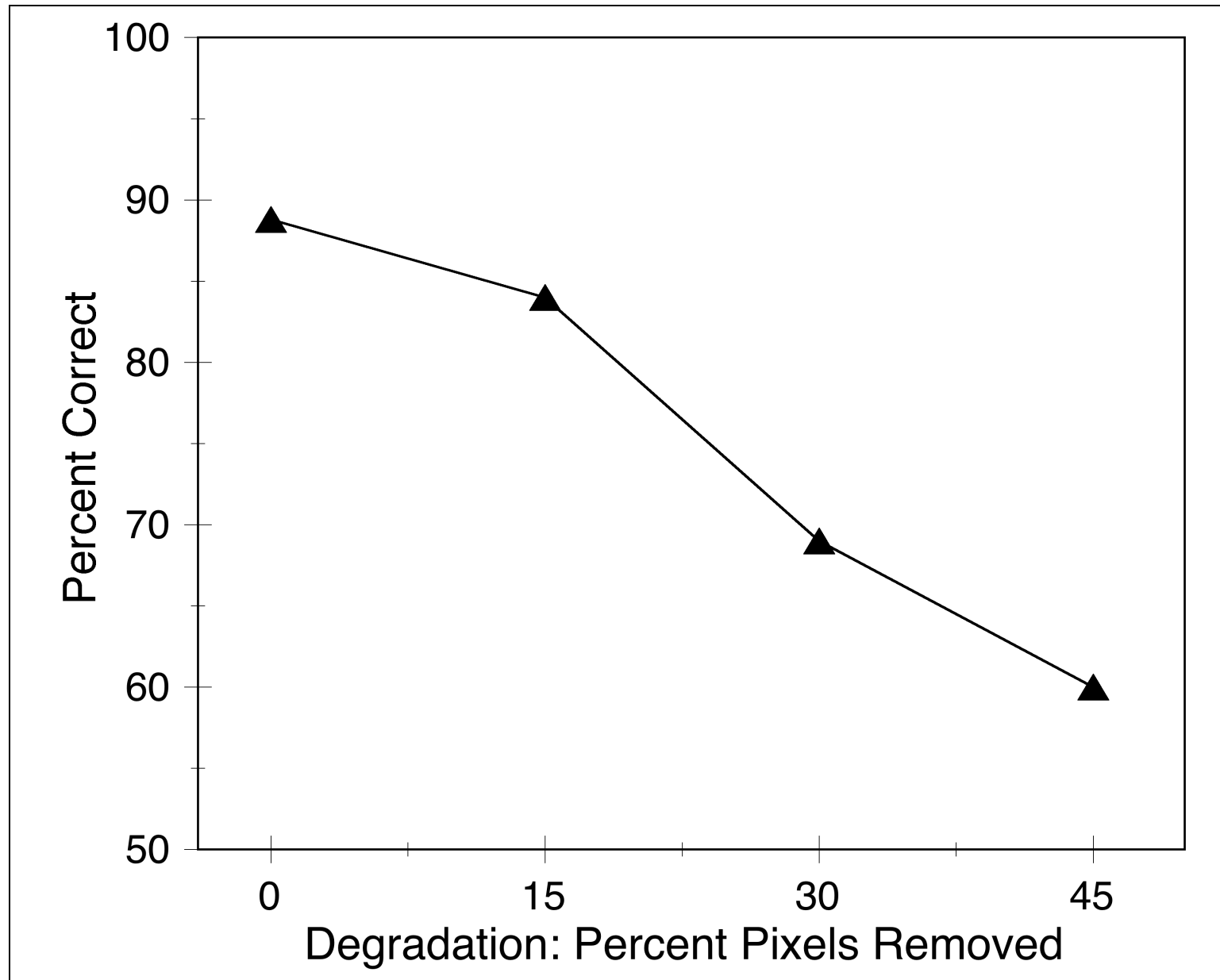
Generic ANOVA Situation

Group 1	Group 2	...	Group j	...	Group J
n_1	n_2		n_j		n_J
X_{11}	X_{12}	...	X_{1j}	...	X_{1J}
X_{21}	X_{22}	...	X_{2j}	...	X_{2J}
\vdots	\vdots		\vdots		\vdots
X_{i1}	X_{i2}	...	X_{ij}	...	X_{iJ}
\vdots	\vdots		\vdots		\vdots
$X_{n_1^1}$	$X_{n_2^2}$	...	$X_{n_j^j}$	...	$X_{n_J^J}$
T_1	T_2	...	T_j	...	T_J
M_1	M_2	...	M_j	...	M_J
SS_1	SS_2	...	SS_j	...	SS_J
$df_1 = n_1 - 1$	$df_2 = n_2 - 1$	...	$df_j = n_j - 1$	...	$df_J = n_J - 1$
$est_1\sigma^2$	$est_2\sigma^2$	...	$est_j\sigma^2$	...	$est_J\sigma^2$

One-Way ANOVA: Data (percent correct)

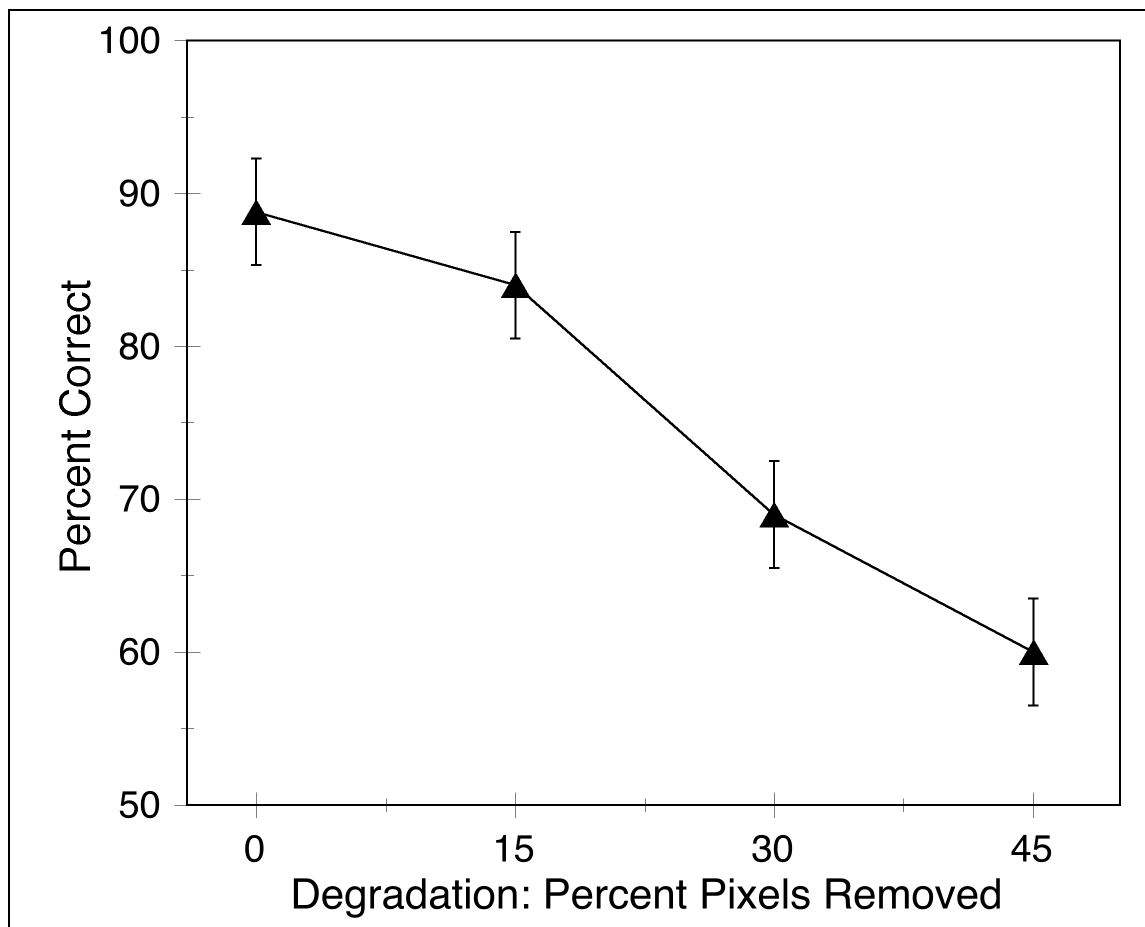
Amount of Degradation (percent pixels removed)					
	0%	15%	30%	45%	J = 4
	$x_{11} = 87$	$x_{12} = 87$	$x_{13} = 74$	$x_{14} = 64$	
	$x_{21} = 90$	$x_{22} = 83$	$x_{23} = 70$	$x_{24} = 61$	
	$x_{31} = 92$	$x_{32} = 81$	$x_{33} = 69$	$x_{34} = 62$	
	$x_{41} = 92$	$x_{42} = 82$	$x_{43} = 62$	$x_{44} = 58$	
	$x_{51} = 83$	$x_{52} = 87$	$x_{53} = 70$	$x_{54} = 55$	
Totals:	$T_1 = 444$	$T_2 = 420$	$T_3 = 345$	$T_4 = 300$	$T = 1,509$
Means:	$M_1 = 88.8$	$M_2 = 84.0$	$M_3 = 69.0$	$M_4 = 60.0$	$M = 75.450$

Graphed Data



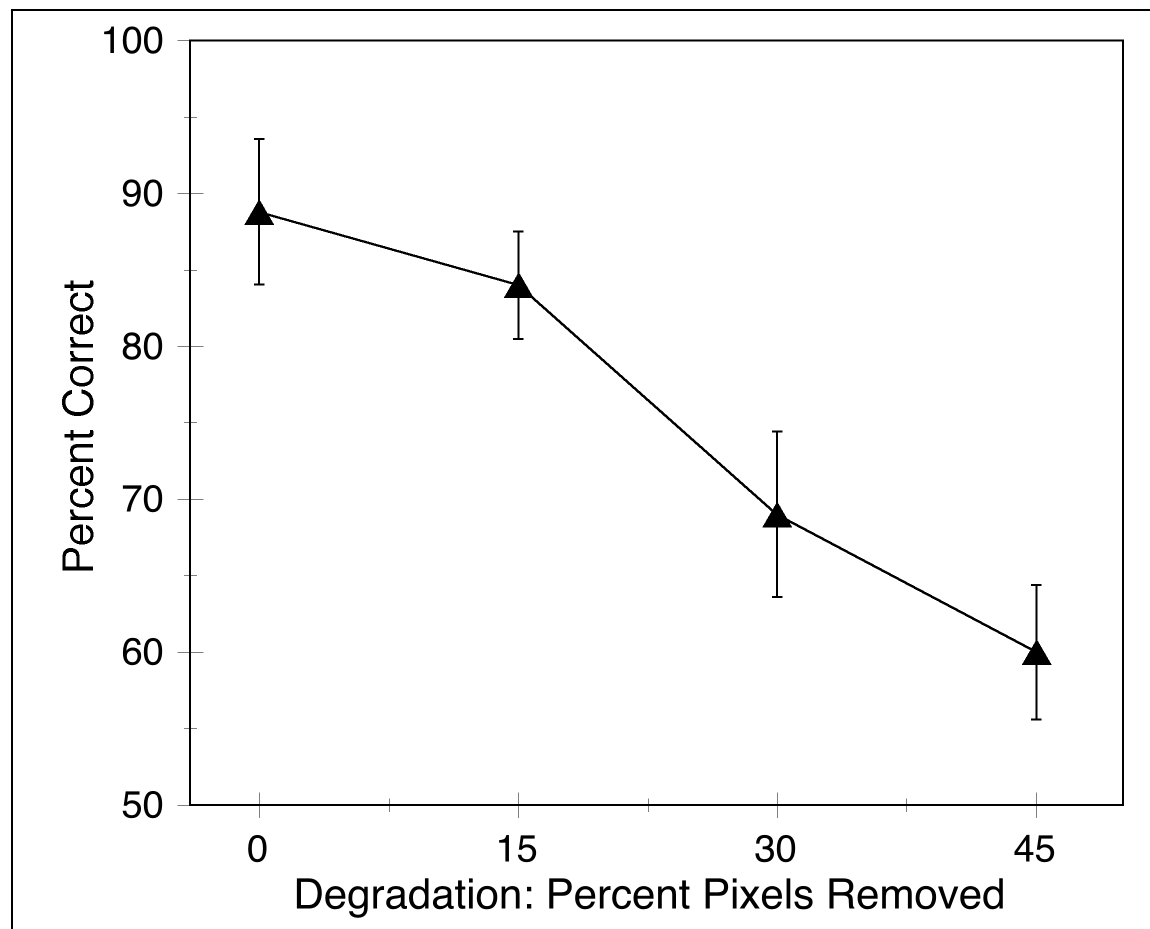
Confidence Intervals (HOV)

est $\sigma_M =$	1.646	1.646	1.646	1.646
crit t =	2.120	2.120	2.120	2.120
CI = \pm	3.49	3.49	3.49	3.49



Confidence Intervals (no HOV)

$\text{est}\sigma_j =$	3.834	2.828	4.359	3.536
$\text{est}\sigma_{M_j} =$	1.715	1.265	1.949	1.581
crit t =	2.776	2.776	2.776	2.776
CI = \pm	4.76	3.51	5.41	4.39



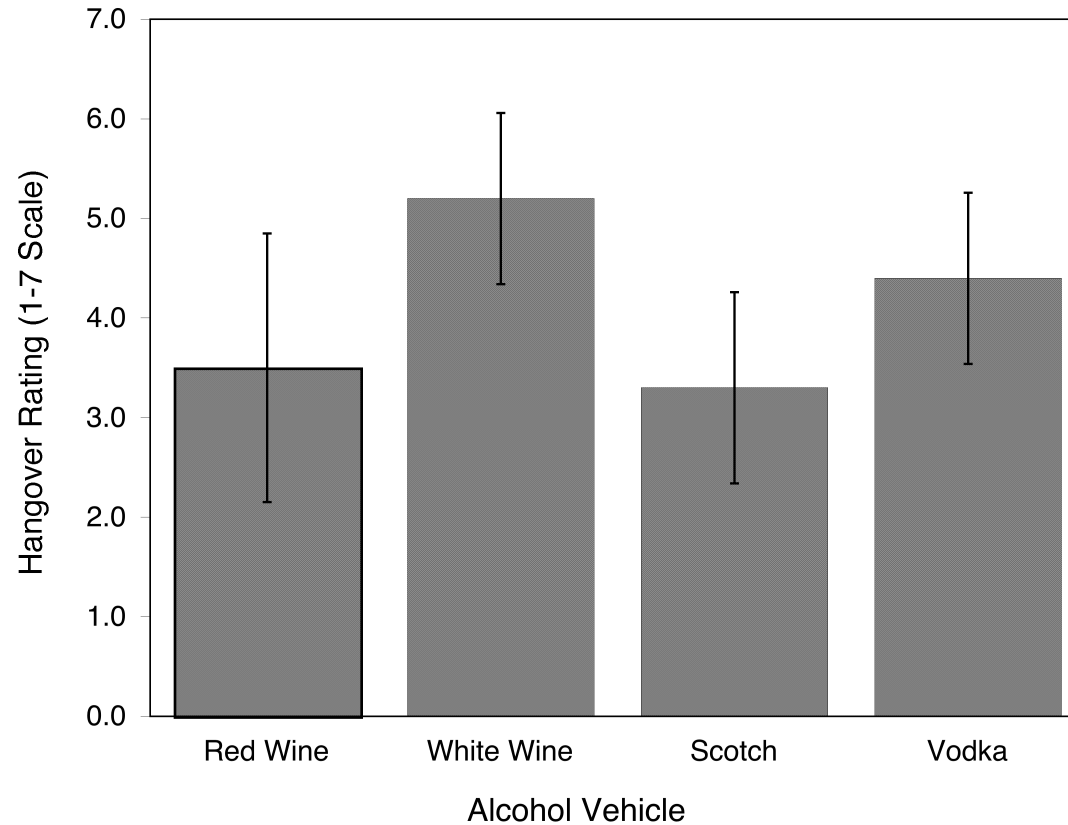
Data (hangover rating)

		Kind of Liquor						
Red Wine		White Wine	Scotch	Vodka	J = 4			
$x_{11} =$	4	$x_{12} =$	5	$x_{13} =$	2	$x_{14} =$	5	
$x_{21} =$	3	$x_{22} =$	5	$x_{23} =$	3	$x_{24} =$	4	
		$x_{32} =$	6	$x_{33} =$	3	$x_{34} =$	5	
		$x_{42} =$	5	$x_{43} =$	5	$x_{44} =$	5	
		$x_{52} =$	5			$x_{54} =$	3	
Totals:	7		26		13		22	T = 68
Means:	3.5		5.2		3.3		4.4	M = 4.088

Confidence Intervals (HOV)

CIs: HOV

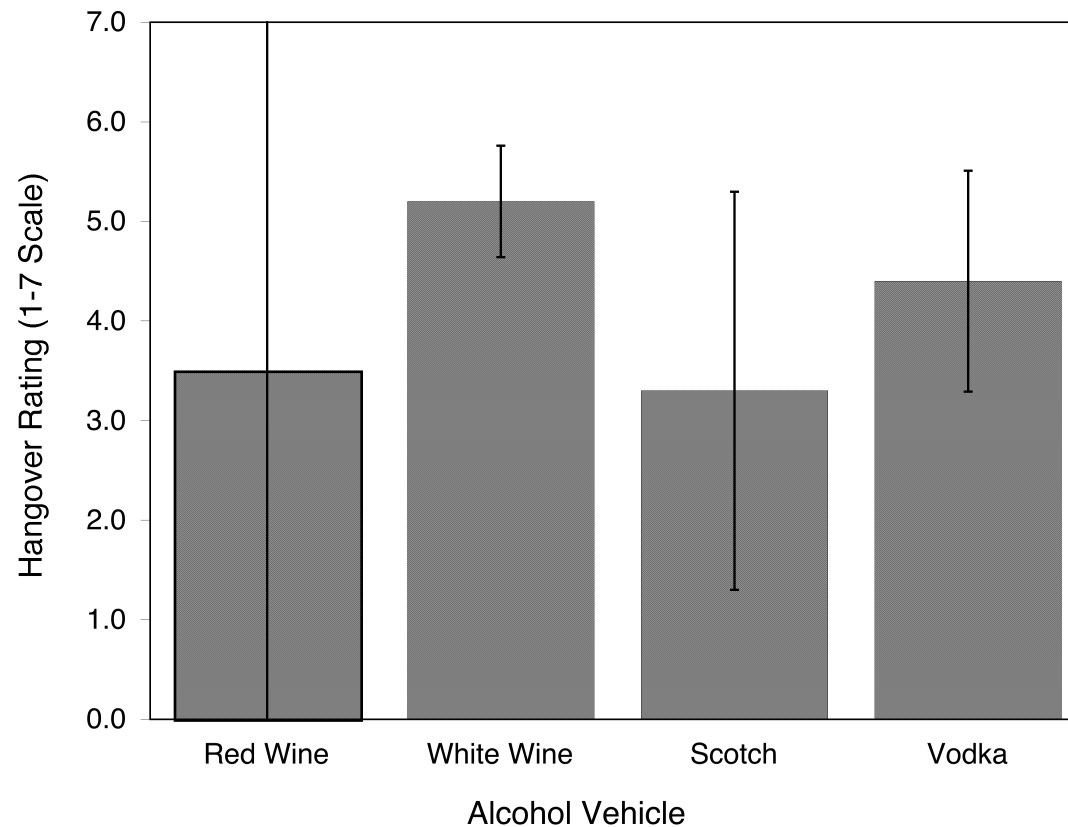
$est\sigma_M =$	0.621	0.393	0.439	0.393
crit t =	2.179	2.179	2.179	2.179
CI = \pm	1.35	0.86	0.96	0.86



Confidence Intervals (non HOV)

CIs: non-HOV

$est\sigma_j =$	0.707	0.447	1.258	0.894
$est\sigma_{Mj} =$	0.500	0.200	0.629	0.400
crit t =	12.706	2.776	3.182	2.776
CI = \pm	6.35	0.56	2.00	1.11



Two Way ANOVA Example: Population Means

		Factor 1: Amount of Degradation (percent pixels removed)				
		Level 1: 0	Level 2: 15	Level 3: 30	Level 4: 45	
Factor 2: Delay Interval	Level 1: Immediate test	$\mu_{11} = 90$	$\mu_{21} = 85$	$\mu_{31} = 70$	$\mu_{41} = 63$	$\mu_{R1} = 77$
	Level 2: One- week delayed test	$\mu_{12} = 66$	$\mu_{22} = 63$	$\mu_{32} = 62$	$\mu_{42} = 61$	$\mu_{R2} = 63$
		$\mu_{C1} = 78$	$\mu_{C2} = 74$	$\mu_{C3} = 66$	$\mu_{C4} = 62$	$\mu = 70$

Data (percent correct)

J = 4

J = 2

n = 5

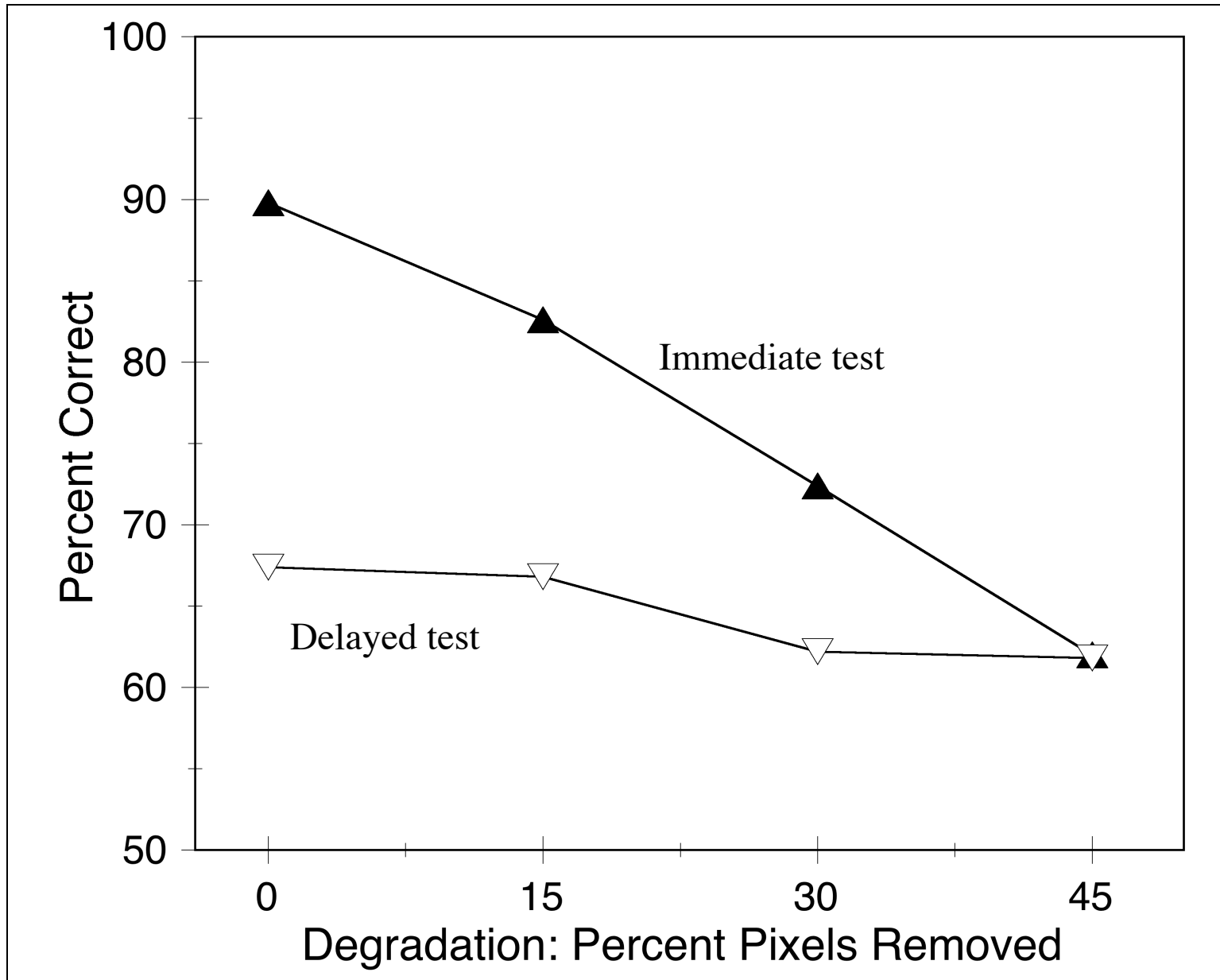
n_C = 10

n_R = 20

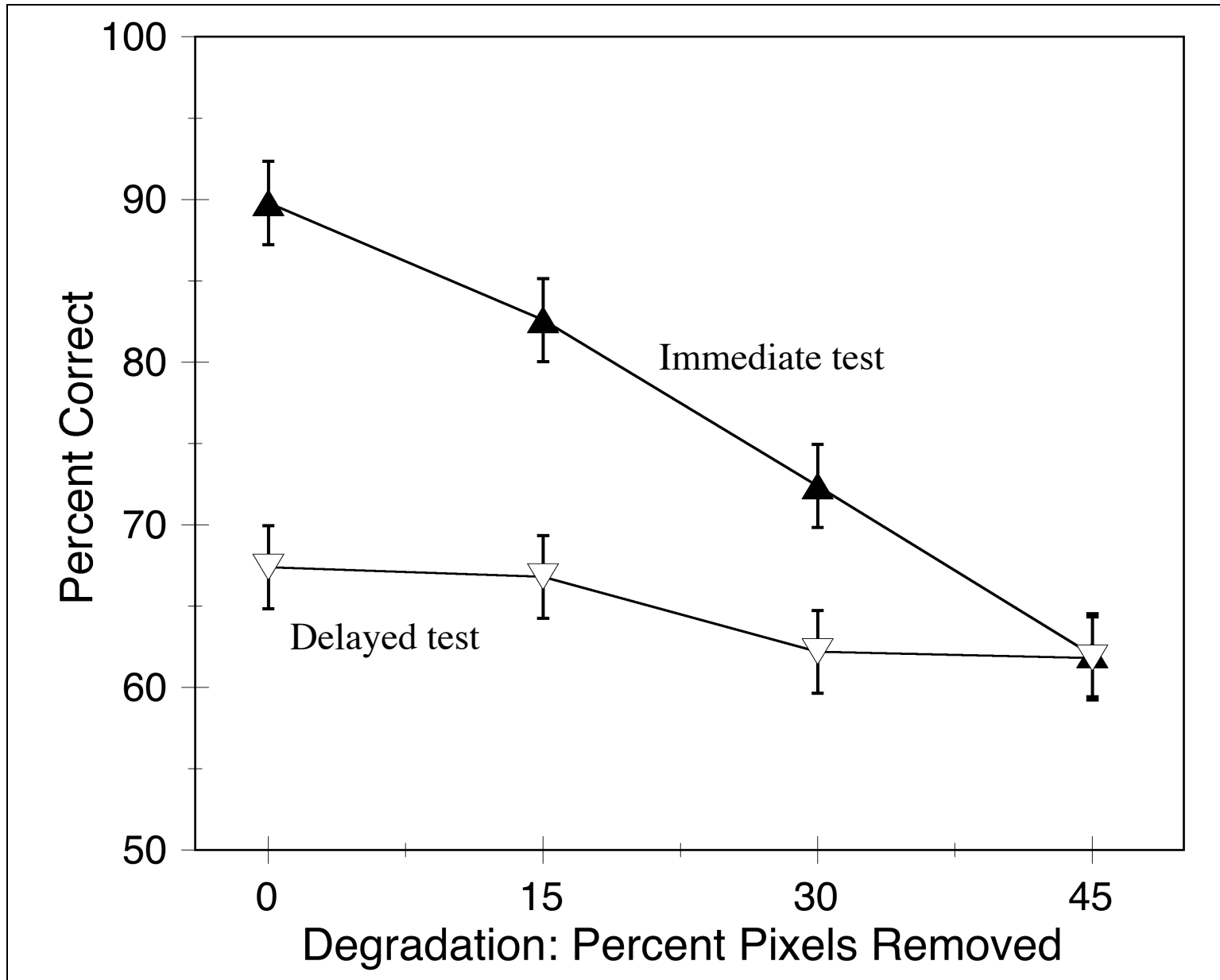
Factor 1: Amount of Degradation (percent pixels removed)

		Level 1: 0	Level 2: 15	Level 3: 30	Level 4: 45		
		Factor 2: Delay Interval		Level 1: Immediate test				T_{R1} = 1,534 M_{R1} = 76.70
x ₁₁₁ = 82	x ₁₂₁ = 81			x ₁₃₁ = 74	x ₁₄₁ = 61		
x ₂₁₁ = 92	x ₂₂₁ = 82			x ₂₃₁ = 73	x ₂₄₁ = 65		
x ₃₁₁ = 94	x ₃₂₁ = 86			x ₃₃₁ = 71	x ₃₄₁ = 63		
x ₄₁₁ = 87	x ₄₂₁ = 81			x ₃₄₁ = 72	x ₄₄₁ = 59		
x ₅₁₁ = 94	x ₅₂₁ = 83			x ₅₃₁ = 72	x ₅₄₁ = 62		
T ₁₁ = 449	T ₂₁ = 413			T ₃₁ = 362	T ₄₁ = 310		
M ₁₁ = 89.8	M ₂₁ = 82.6			M ₃₁ = 72.4	M ₄₁ = 62.0		
Level 2: One-week delayed test				T _{R2} = 1,291 M _{R2} = 64.55			
x ₁₁₂ = 68	x ₁₂₂ = 63				x ₁₃₂ = 61	x ₁₄₂ = 60	
x ₂₁₂ = 67	x ₂₂₂ = 68	x ₂₃₂ = 66	x ₂₄₂ = 64				
x ₃₁₂ = 66	x ₃₂₂ = 69	x ₃₃₂ = 65	x ₃₄₂ = 65				
x ₄₁₂ = 67	x ₄₂₂ = 68	x ₃₄₂ = 60	x ₄₄₂ = 58				
x ₅₁₂ = 69	x ₅₂₂ = 66	x ₅₃₂ = 59	x ₅₄₂ = 62				
T ₁₂ = 337	T ₂₂ = 334	T ₃₂ = 311	T ₄₂ = 309				
M ₁₂ = 67.4	M ₂₂ = 66.8	M ₃₂ = 62.2	M ₄₂ = 61.8				
T _{C1} = 786	T _{C2} = 747	T _{C3} = 673	T _{C4} = 619		T = 2,825		
M _{C1} = 78.6	M _{C2} = 74.7	M _{C3} = 67.3	M _{C4} = 61.9		M = 70.625		
					N = 40		

Plot Data



Plot Data (with confidence intervals)



Data (Ignore Row Variable)

Factor 1: Amount of Degradation (percent pixels removed)

Level 1: 0	Level 2: 15	Level 3: 30	Level 4: 45	
$x_{111} = 82$	$x_{121} = 81$	$x_{131} = 74$	$x_{141} = 61$	
$x_{211} = 92$	$x_{221} = 82$	$x_{231} = 73$	$x_{241} = 65$	
$x_{311} = 94$	$x_{321} = 86$	$x_{331} = 71$	$x_{341} = 63$	
$x_{411} = 87$	$x_{421} = 81$	$x_{341} = 72$	$x_{441} = 59$	
$x_{511} = 94$	$x_{521} = 83$	$x_{531} = 72$	$x_{541} = 62$	
$x_{112} = 68$	$x_{122} = 63$	$x_{132} = 61$	$x_{142} = 60$	
$x_{212} = 67$	$x_{222} = 68$	$x_{232} = 66$	$x_{242} = 64$	
$x_{312} = 66$	$x_{322} = 69$	$x_{332} = 65$	$x_{342} = 65$	
$x_{412} = 67$	$x_{422} = 68$	$x_{342} = 60$	$x_{442} = 58$	
$x_{512} = 69$	$x_{522} = 66$	$x_{532} = 59$	$x_{542} = 62$	
$T_{C1} = 786$	$T_{C2} = 747$	$T_{C3} = 673$	$T_{C4} = 619$	$T = 2,825$
$M_{C1} = 78.6$	$M_{C2} = 74.7$	$M_{C3} = 67.3$	$M_{C4} = 61.9$	$M = 70.625$

$N = 40$

Data (Ignore Column Variable)

Delay Interval	Immediate test	$x_{111} = 82$	$x_{121} = 81$	$x_{131} = 74$	$x_{141} = 61$	$T_{R1} = 1,534$
		$x_{211} = 92$	$x_{221} = 82$	$x_{231} = 73$	$x_{241} = 65$	
		$x_{311} = 94$	$x_{321} = 86$	$x_{331} = 71$	$x_{341} = 63$	
		$x_{411} = 87$	$x_{421} = 81$	$x_{341} = 72$	$x_{441} = 59$	
		$x_{511} = 94$	$x_{521} = 83$	$x_{531} = 72$	$x_{541} = 62$	
	Delayed test	$x_{112} = 68$	$x_{122} = 63$	$x_{132} = 61$	$x_{142} = 60$	$T_{R2} = 1,291$
		$x_{212} = 67$	$x_{222} = 68$	$x_{232} = 66$	$x_{242} = 64$	
		$x_{312} = 66$	$x_{322} = 69$	$x_{332} = 65$	$x_{342} = 65$	
		$x_{412} = 67$	$x_{422} = 68$	$x_{342} = 60$	$x_{442} = 58$	
		$x_{512} = 69$	$x_{522} = 66$	$x_{532} = 59$	$x_{542} = 62$	

$T = 2,825$

$N = 40$

Analysis of Simple Effects (Immediate test)

	Level 1: 1	Level 2: 15	Level 3: 30	Level 4: 45	
Level 1: Immediate test	$x_{111} = 82$	$x_{121} = 81$	$x_{131} = 74$	$x_{141} = 61$	
	$x_{211} = 92$	$x_{221} = 82$	$x_{231} = 73$	$x_{241} = 65$	
	$x_{311} = 94$	$x_{321} = 86$	$x_{331} = 71$	$x_{341} = 63$	
	$x_{411} = 87$	$x_{421} = 81$	$x_{341} = 72$	$x_{441} = 59$	
	$x_{511} = 94$	$x_{521} = 83$	$x_{531} = 72$	$x_{541} = 62$	
	$T_{11} = 449$	$T_{21} = 413$	$T_{31} = 362$	$T_{41} = 310$	$T_{R1} = 1,534$
	$M_{11} = 89.8$	$M_{21} = 82.6$	$M_{31} = 72.4$	$M_{41} = 62.0$	$M_{R1} = 76.70$

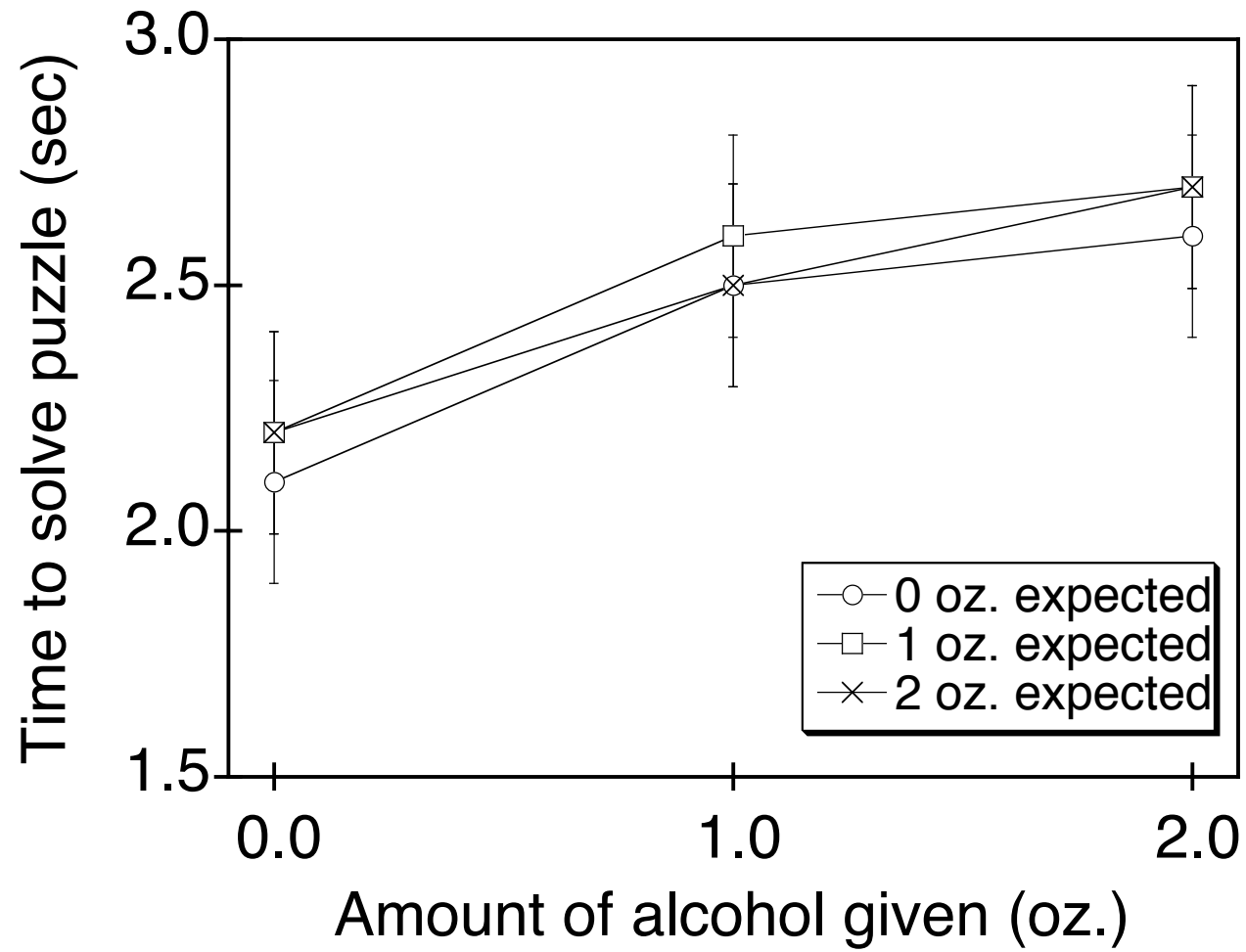
Analysis of Simple Effects (Delayed test)

	Level 1: 1	Level 2: 15	Level 3: 30	Level 4: 45	
Level 2: One-week delayed test	$x_{112} = 68$	$x_{122} = 63$	$x_{132} = 61$	$x_{142} = 60$	
	$x_{212} = 67$	$x_{222} = 68$	$x_{232} = 66$	$x_{242} = 64$	
	$x_{312} = 66$	$x_{322} = 69$	$x_{332} = 65$	$x_{342} = 65$	
	$x_{412} = 67$	$x_{422} = 68$	$x_{342} = 60$	$x_{442} = 58$	
	$x_{512} = 69$	$x_{522} = 66$	$x_{532} = 59$	$x_{542} = 62$	
	$T_{12} = 337$	$T_{22} = 334$	$T_{32} = 311$	$T_{42} = 309$	$T_{R2} = 1,291$
	$M_{12} = 67.4$	$M_{22} = 66.8$	$M_{32} = 62.2$	$M_{42} = 61.8$	$M_{R2} = 64.55$

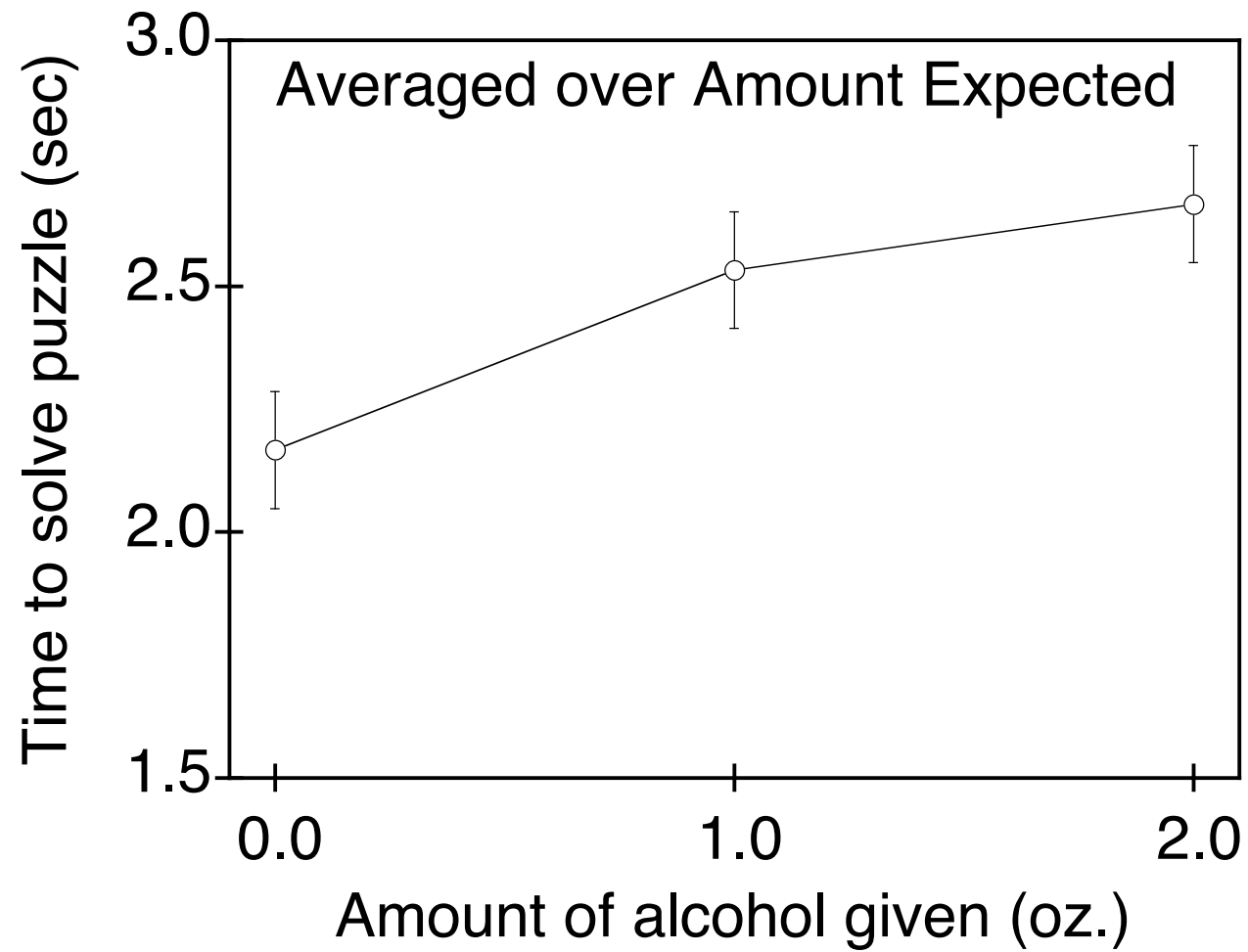
Data: Acohol

	Level 1 (control) (No alcohol given)	Level 2 (1 oz alcohol given)	Level 3 (2 oz alcohol given)	
Level 1 (Control) No alcohol expected	2.0	2.5	2.4	
	2.0	2.5	2.6	
	2.3	2.5	2.8	
	T₁₁ = 6.3 M₁₁ = 2.1	T₂₁ = 7.5 M₂₁ = 2.5	T₃₁ = 7.8 M₃₁ = 2.6	T_{R1} = 21.6 M_{R1} = 2.40
Level 2 1 oz alcohol expected	2.3	2.4	2.7	
	2.2	2.4	2.6	
	2.1	3.0	2.8	
	T₁₂ = 6.6 M₁₂ = 2.2	T₂₂ = 7.8 M₂₂ = 2.6	T₃₂ = 8.1 M₃₂ = 2.7	T_{R2} = 22.5 M_{R2} = 2.50
Level 3 2 oz alcohol expected	2.2	2.4	2.9	
	2.2	2.6	2.5	
	2.2	2.5	2.7	
	T₁₃ = 6.6 M₁₃ = 2.2	T₂₃ = 7.5 M₂₃ = 2.5	T₃₃ = 8.1 M₃₃ = 2.7	T_{R1} = 22.2 M_{R1} = 2.47
	T_{C1} = 19.5 M_{C1} = 2.17	T_{C3} = 22.8 M_{C3} = 2.53	T_{C3} = 24.0 M_{C3} = 2.67	T = 66.3 N = 27

Plot: All Data



Plot: Averaged over Amount Expected

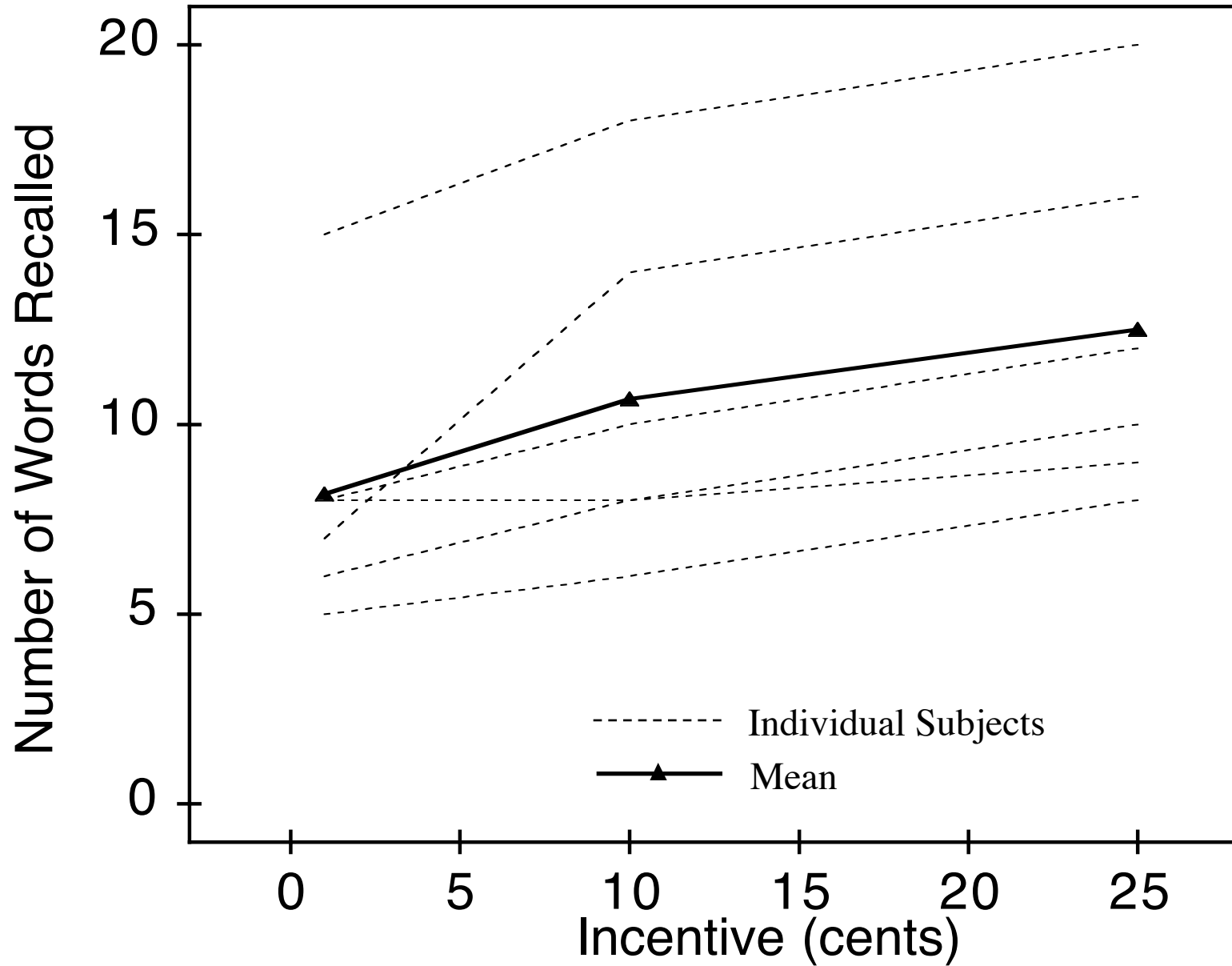


Data

Incentive Condition

Subject	1 cent	10 cents	25 cents	
1	8	10	12	$T_{R1} = 30$
2	15	18	20	$T_{R2} = 53$
3	6	8	9	$T_{R3} = 23$
4	8	8	10	$T_{R4} = 26$
5	7	14	16	$T_{R5} = 37$
6	5	6	8	$T_{R6} = 19$
	$T_{C1} = 49$	$T_{C2} = 64$	$T_{C3} = 75$	$T = 188$
	$M_{C1} = 8.17$	$M_{C2} = 10.67$	$M_{C3} = 12.50$	$N = 18$

Graphed Data



Removing Subject Variance

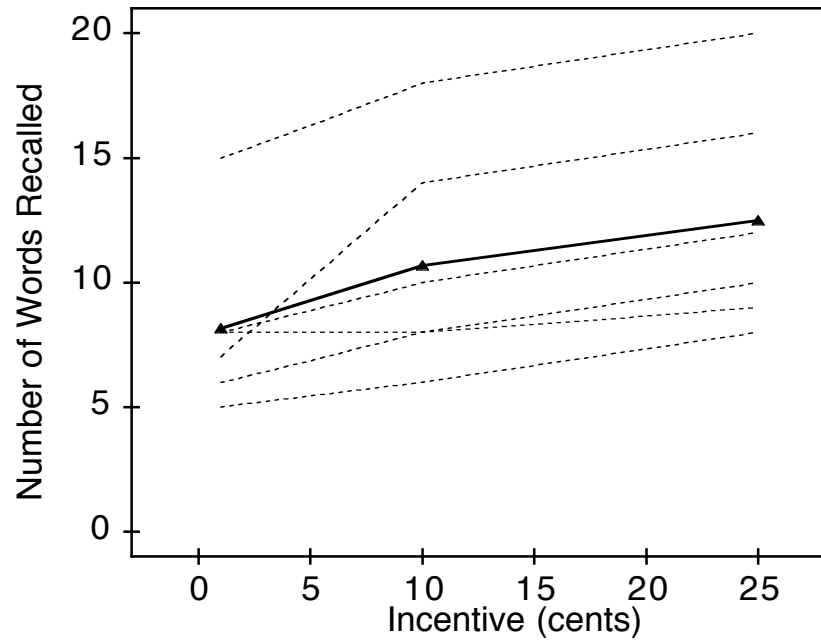
Subject	1	10	25	Mean	Correction = C_j
1	8	10	12	$M_1 = 10.00$	$10.00 - 10.44 = -0.44$
2	15	18	20	$M_2 = 17.67$	$17.67 - 10.44 = 7.22$
3	6	8	9	$M_3 = 7.67$	$7.67 - 10.44 = -2.78$
4	8	8	10	$M_4 = 8.67$	$8.67 - 10.44 = -1.78$
5	14	14	16	$M_5 = 12.33$	$12.33 - 10.44 = 1.89$
6	6	6	8	$M_6 = 6.33$	$6.33 - 10.44 = -4.11$
Mean	8.17	10.67	12.50	M = 10.44	M = 0.00

$$X_{ij}' = X_{ij} - C_j$$

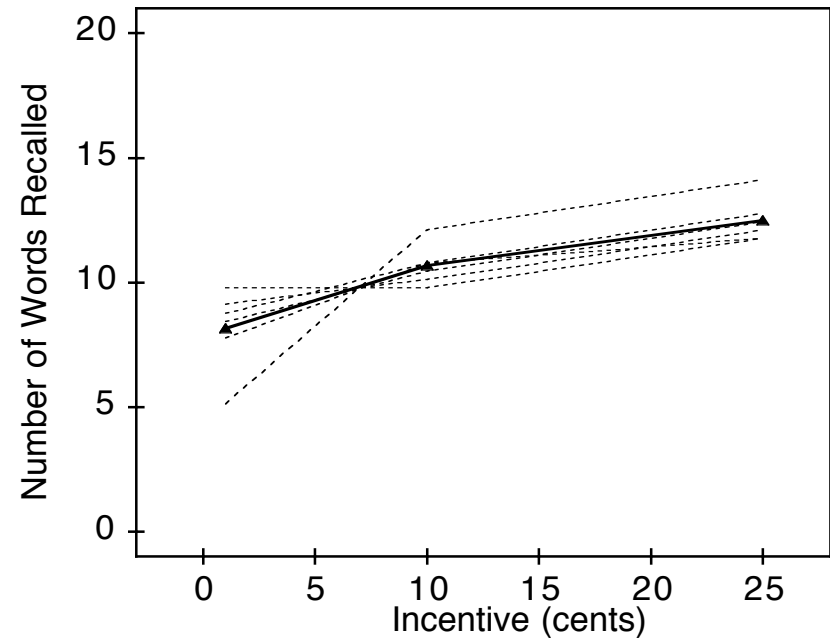
Subject	1	10	25	Mean
1	8.44	10.44	12.44	$M_1 = 10.44$
2	7.78	10.78	12.78	$M_2 = 10.44$
3	8.78	10.78	11.78	$M_3 = 10.44$
4	9.78	9.78	11.78	$M_4 = 10.44$
5	5.11	12.11	14.11	$M_5 = 10.44$
6	9.11	10.11	12.11	$M_6 = 10.44$
Mean	8.17	10.67	12.50	M = 10.44

Graphed Data

Original



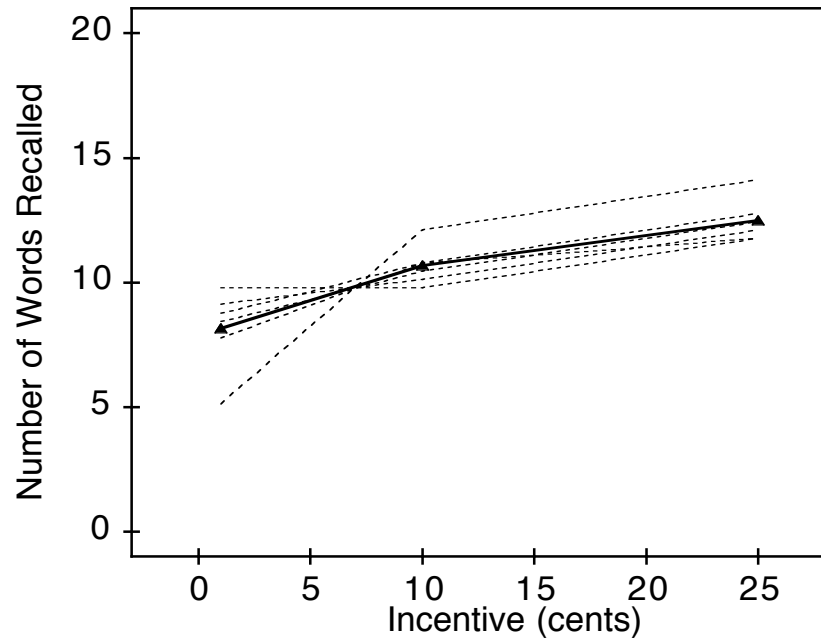
No Subject Variance



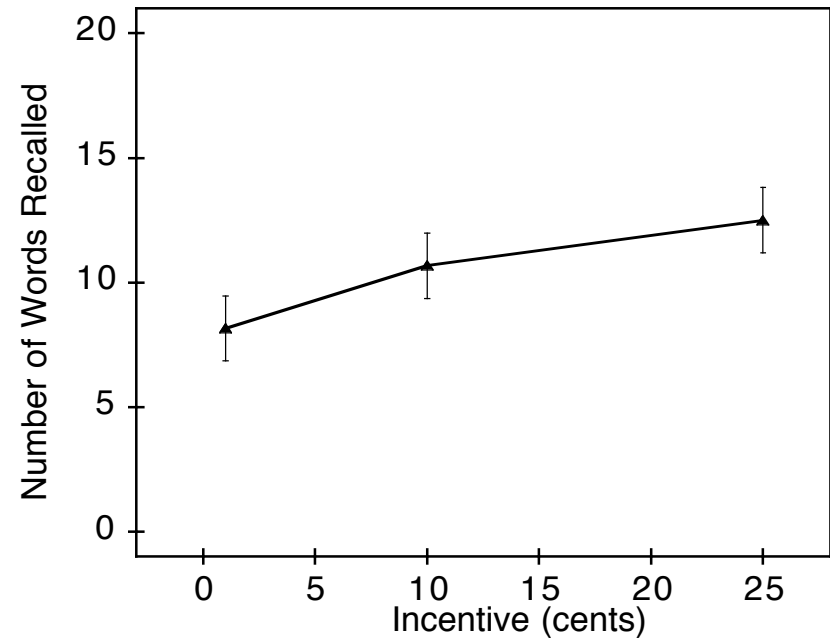
----- Individual Subjects
——▲—— Mean

Confidence Intervals

Indvd. Subjects



Means



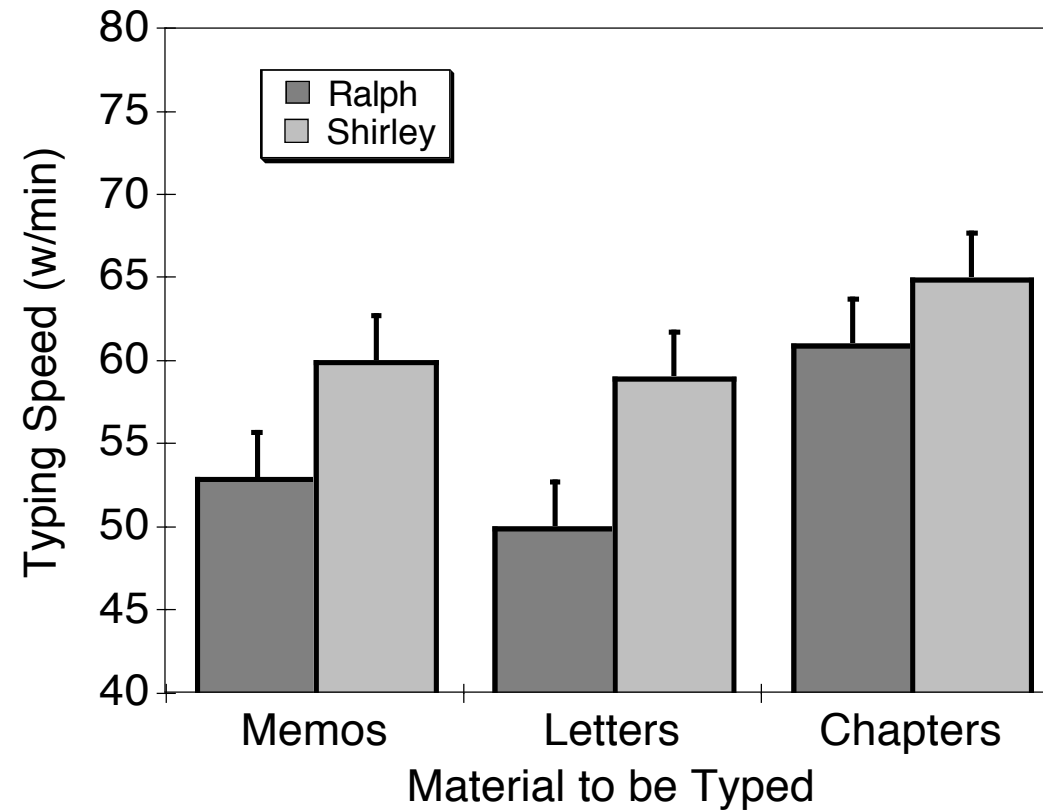
Multiple Observations per Subject

Subject	Incentive Condition			
	1 cent	10 cents	25 cents	
1	7 9 8 $T_{11} = 24$ $M_{11} = 8$	10 10 10 $T_{21} = 30$ $M_{21} = 10$	11 13 12 $T_{31} = 36$ $M_{31} = 12$	$T_{R1} = 90$
2	13 15 17 $T_{12} = 45$ $M_{12} = 15$	19 18 17 $T_{22} = 54$ $M_{22} = 18$	20 20 20 $T_{32} = 60$ $M_{32} = 20$	$T_{R2} = 159$
3	6 6 6 $T_{13} = 18$ $M_{13} = 6$	8 6 10 $T_{23} = 24$ $M_{23} = 8$	9 10 8 $T_{33} = 27$ $M_{33} = 9$	$T_{R3} = 69$
4	9 8 7 $T_{14} = 24$ $M_{14} = 8$	8 8 8 $T_{24} = 24$ $M_{24} = 8$	10 10 10 $T_{34} = 30$ $M_{34} = 10$	$T_{R4} = 78$
5	7 10 4 $T_{15} = 21$ $M_{15} = 7$	14 15 13 $T_{25} = 42$ $M_{25} = 14$	16 15 17 $T_{35} = 48$ $M_{35} = 16$	$T_{R5} = 111$
6	5 5 5 $T_{16} = 15$ $M_{16} = 5$	6 5 7 $T_{26} = 18$ $M_{26} = 6$	8 10 6 $T_{36} = 24$ $M_{36} = 8$	$T_{R6} = 57$
	$T_{C1} = 147$ $M_{C1} = 8.17$	$T_{C2} = 192$ $M_{C2} = 10.67$	$T_{C3} = 225$ $M_{C3} = 12.50$	$T = 564$ $N = 54$

Typing Speeds

		Type of Material			
		Memos	Letters	Chapters	
Typist	Ralph	$x_{111} = 51$	$x_{211} = 47$	$x_{311} = 62$	
		$x_{112} = 56$	$x_{212} = 50$	$x_{312} = 62$	
		$x_{113} = 52$	$x_{213} = 53$	$x_{313} = 59$	
	$T_{11} = 159$	$T_{21} = 150$	$T_{31} = 183$	$T_{R1} = 492$	
	$M_{11} = 53$	$M_{21} = 50$	$M_{31} = 61$	$M_{R1} = 54.67$	
Shirley		$x_{121} = 58$	$x_{221} = 60$	$x_{321} = 63$	
		$x_{122} = 60$	$x_{222} = 60$	$x_{322} = 65$	
		$x_{123} = 62$	$x_{223} = 57$	$x_{323} = 67$	
		$T_{12} = 180$	$T_{22} = 177$	$T_{32} = 195$	$T_{R2} = 552$
		$M_{12} = 60$	$M_{22} = 59$	$M_{32} = 65$	$M_{R2} = 61.33$
	$T_{C1} = 339$	$T_{C2} = 327$	$T_{C3} = 378$	$T = 1,044$	
	$M_{C1} = 56.5$	$M_{C2} = 54.5$	$M_{C3} = 63.0$	$N = 18$	
				$M = 58.0$	

Graph Assuming “Typist” is a Fixed Effect



Two-Way Within-Subjects Designs

Data are percent correct from a two-way recognition experiment in which column variable is degree of degradation (0 - 45% removed) and row variable is delay (0/1 week)

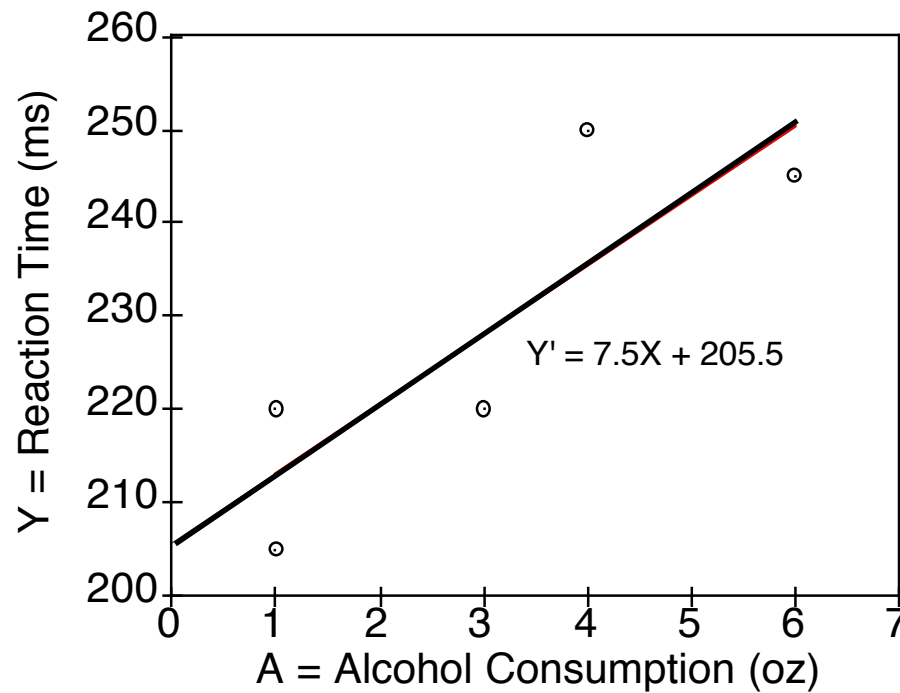
Subject 1			
83	82	78	61
66	68	64	60
Subject 2			
92	93	88	89
87	88	86	85
Subject 3			
77	78	65	54
48	47	45	40
Subject 4			
78	76	65	68
65	64	70	61
Subject 5			
99	99	95	94
90	91	94	93
Subject 6			
88	85	80	75
72	71	67	66
Mean Data			
86.17	85.50	78.50	73.50
67.50	71.50	71.00	67.50

ANOVA Table from Within-Subjects Two-Way Design

Source	df	SS	MS	F
Subjects (S)	5	7,640.50		
Columns (C)	3	540.75	180.15	$\frac{MS_C}{MS_{S \times C}} = 10.86$
Rows (R)	1	1,344.08	1,344.08	$\frac{MS_R}{MS_{S \times R}} = 12.65$
SxC	5x3 = 15	249.00	16.60	
SxR	5x1 = 5	531.17	106.23	
CxR	3x1 = 3	180.75	60.25	$\frac{MS_{C \times R}}{MS_{S \times C \times R}} = 6.60$
SxCxR	5x3x1 = 15	137.00	9.13	
Total	48 - 1 = 47	10,613.25		

Example of Regression

Subject	X = Alcohol Consumption (oz)	Y = Reaction Time (ms)	Y' = 7.5X + 205.5	Error = (Y - Y')
1	3	220	228	-8.0
2	1	205	213	-8.0
3	1	220	213	7.0
4	4	250	235.5	14.5
5	6	245	250.5	-5.5



Example of Using Planned Comparisons

n = 15

Set size =	1	2	3	4	5	
M _{js} =	325	368	382	425	460	
T _{js} =	4,875	5,520	5,730	6,375	6,900	T = 29,400
						N = 75

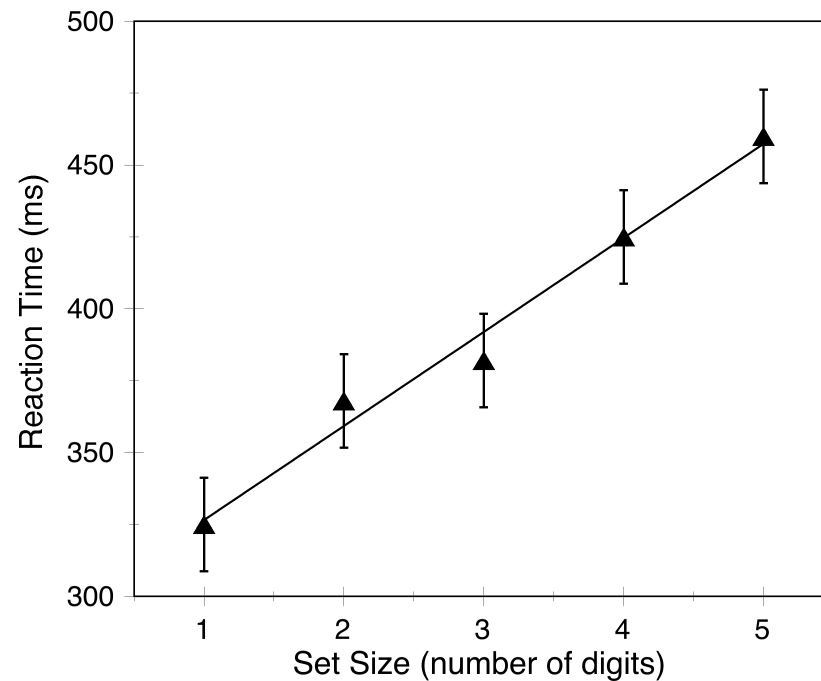
ANOVA		$\alpha = 0.05$			
Source	df	SS	MS	Obtained F	Criterion F
Between	4	163,170	40,792.5	40.79	2.50
Within	70	70,000	1,000.0		

CONFIDENCE INTERVAL: 95%

$$\text{est}\sigma_M = 8.16$$

$$\text{crit } t = 1.99$$

$$\text{CI} = \pm 16.28$$



Multiple Planned Comparisons

	n = 10					
	Control	VP-Boeing	VP-Microsoft	Clerk-Boeing	Clerk-Microsoft	
$M_{js} =$	1.8	3.5	3.7	2.4	2.8	
$T_{js} =$	18	35	37	24	28	T = 142 N = 50

CONFIDENCE INTERVAL: 95%

$$\text{est}\sigma_M = 0.22$$

$$\text{crit } t = 2.01$$

$$\text{CI} = \pm 0.45$$

