INTERNAL CONSISTENCY OF INDICATORS OF PERFORMANCE ON TEMPORAL DISCRIMINATION AND RESPONSE TIMES AS OBTAINED BY ADAPTIVE PSYCHOPHYSICAL PROCEDURES

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Abstract

In two temporal-discrimination studies, sensitivity of the transformed up-down method and the weighted up-down method was evaluated. Internal consistency of difference-threshold estimates and response times, as indicated by Cronbach's alpha, ranged from .82 to .99. The high level of internal consistency endorse the view that adaptive psychophysical methods provide a highly sensitive and reliable technique for assessment of timing performance in humans.

Over the last two decades, an increasing number of studies on temporal discrimination used adaptive psychophysical procedures to obtain individual performance estimates. 'Adaptive' means that the stimulus is adjusted on the basis of previous responses in an attempt to determine the stimulus value required to produce a specified level of performance. A major advantage of adaptive methods is their efficiency. With traditional psychophysical methods a large amount of data is wasted since the stimulus is often presented far from threshold where little information is gained.

Two of the most commonly employed adaptive psychophysical procedures are the transformed up-down method using a 2-step rule (Levitt, 1971) and the weighted up-down method (Kaernbach, 1991) which can be seen as a modification of Derman's (1957) version of the simple up-down procedure. The present paper reports two studies designed to evaluate the sensitivity of both these adaptive procedure for assessment of temporal discrimination performance in humans.

In Study 1, Cronbach's alpha (e.g., Cronbach, 1990) was computed across 20 threshold estimates for temporal discrimination of filled and empty auditory intervals with a base duration of 50 ms. In Study 2, Cronbach's alpha was computed across 12 threshold estimates for temporal discrimination of filled auditory intervals with base durations of 50 and 1,000 ms. In addition to threshold estimates, sensitivity of response latencies was also assessed.

Study 1

Participants

Two male and four female students ranging from 20 to 37 years of age (mean age: 27.0 years) and four male and two female students ranging in age from 25 to 36 years (mean age: 30.2 years) participated in Experiments 1A and 1B, respectively.

Apparatus and Stimuli

Auditory stimuli were generated by a computer-controlled sound generator. In Experiment 1A, a square wave with a frequency of 1,000 Hz and an intensity of 67 dB (SPL) was used; in Experiment 1B, the participants were confronted with empty intervals marked by 3-ms clicks with an intensity of 88 dB (SPL). All stimuli were presented through headphones (Vivanco Model SR85).

Procedure

Each participant was run individually on 20 consecutive daily testing sessions starting on a Monday and omitting weekends; that is, there were four weeks of testing of five sessions each. An experimental session consisted of 50 trials, and each trial consisted of two stimuli, one 50-ms standard interval, and one comparison interval. The comparison interval varied in duration from trial to trial, depending on the participant's previous responses according to the transformed up-down procedure, which converges on a probability of hits of .707. The duration of the comparison interval changed with a constant step size of 8 ms for Trials 1-10, 4 ms for Trials 11-30, and 2 ms for Trials 31-50. The initial value of the comparison interval was 98 ms. The order of presentation for the standard interval and the comparison interval was randomized and balanced, with each interval being presented first in 50% of the trials.

To initiate a trial, the participant pressed the space bar of a computer keyboard; the auditory presentation began 900 ms later. The two intervals were presented with an interstimulus interval of 900 ms. The participant's task was to decide which of the two intervals was longer and to indicate his or her decision by pressing one of two designated keys of the keyboard. The instructions to the participants emphasized accuracy; there was no requirement to respond quickly. After each response, visual feedback ("+" = correct or "-" = false) was displayed.

As a measure of duration discrimination performance, mean differences between standard intervals and comparison intervals were computed for the last 20 trials of each daily testing session. This measure represents an estimate of the individual 70.7% difference threshold in milliseconds in relation to a standard interval of 50 ms. Response times were also averaged across the last 20 trials.

Results

Figure 1 displays the results of each participant from Experiments 1A and 1B. Cronbach's alpha was computed across both the 20 threshold estimates and the respective response times. The resulting alpha coefficients were .95 and .99 for the threshold estimates with filled and empty intervals, respectively. Similar results were obtained for the response times; alpha coefficients were .96 and .98 for Experiments 1A and 1B, respectively.

Table 1. Threshold estimates (TE) and response times (RT) as a function of session number (Participants 1-6: filled intervals; Participants 7-12: empty intervals).

Participant		Session number																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	TE	5.0	5.6	5.5	4.1	3.8	6.3	4.2	7.1	6.5	3.9	6.1	6.9	3.6	5.3	5.0	11.9	3.1	6.9	4.3	3.8
	RT	1905	1424	1302	856	824	949	780	1133	916	1094	970	886	949	700	668	537	471	635	439	908
2	TE	5.8	6.7	11.4	13.0	16.8	8.7	13.6	12.5	9.0	9.6	8.6	7.4	12.4	9.4	10.0	9.5	9.7	5.0	10.1	7.3
	RT	1589	1087	1509	1355	1126	869	601	1264	1172	1004	1418	1233	1036	902	956	1039	591	881	717	639
3	TE	11.6	10.3	11.3	8.8	5.4	9.4	7.8	7.3	7.9	5.2	11.0	4.5	6.0	6.5	4.0	7.4	4.6	5.0	9.6	6.8
	RT	1824	719	664	631	728	598	513	523	404	352	313	459	599	629	566	455	520	665	461	382
4	TE	3.6	7.0	3.7	4.3	3.7	5.6	3.2	4.1	4.9	5.4	5.2	2.8	3.1	3.8	4.3	3.1	3.1	4.6	4.3	4.2
	RT	615	544	622	620	667	534	569	629	506	504	626	490	675	534	560	460	566	490	423	495
5	TE	3.4	6.1	3.1	3.2	4.3	3.2	3.0	3.5	3.3	6.0	4.8	3.3	3.4	4.9	7.6	5.4	3.6	5.2	7.2	4.1
	RT	1330	1244	1584	1209	1277	1470	1246	1549	822	871	1050	611	904	1271	962	873	614	1059	1197	880
6	TE	11.2	14.4	20.1	10.3	4.0	3.6	7.9	8.5	12.0	5.7	16.4	6.2	7.9	18.9	15.3	15.0	16.2	13.5	20.0	3.4
	RT	1105	1005	718	1156	1067	741	844	767	627	613	602	790	657	581	501	502	543	491	538	519
7	TE	28.3	23.2	31.7	13.0	16.5	14.2	14.0	15.8	25.1	8.5	11.2	10.5	16.8	11.2	18.0	12.2	10.9	4.9	7.3	8.4
	RT	1431	1196	1425	1294	1458	1511	1719	2433	1577	1517	1044	2206	1786	1640	1288	1659	1421	1227	1229	1481
8	TE	43.0	39.3	27.8	18.5	23.7	9.7	18.1	4.6	9.6	25.0	13.8	7.3	12.9	14.2	21.6	26.3	12.1	25.0	26.4	35.8
	RT	613	538	654	562	558	628	553	507	624	640	839	837	583	852	620	707	654	505	457	548
9	TE	7.6	10.4	9.0	5.5	5.2	4.4	9.1	4.7	6.8	7.0	4.3	5.4	7.2	5.4	5.7	5.9	6.2	3.3	5.1	5.4
	RT	2108	1473	1278	1177	980	1596	850	1008	1103	1151	1373	726	1166	847	709	919	1100	1108	1131	841
10	TE	5.1	12.1	10.8	11.4	6.9	6.7	7.8	9.1	3.3	5.6	4.2	7.7	5.0	6.2	6.7	4.1	4.5	12.4	4.9	9.8
	RT	561	579	538	641	650	537	634	659	560	478	455	562	487	475	623	535	630	675	770	533
11	TE	5.0	5.9	3.7	9.3	6.2	10.5	8.4	3.2	11.7	7.2	4.9	7.5	7.5	5.5	10.4	6.8	4.6	7.6	7.4	8.7
	RT	1045	994	920	1025	1095	775	1049	1089	1299	662	938	751	638	513	1043	782	589	702	888	539
12	TE	4.9	4.7	7.2	5.5	12.0	9.4	4.1	7.8	5.1	6.4	6.9	5.1	5.1	4.7	11.5	8.1	4.1	4.9	6.4	6.2
	RT	915	1365	1097	902	831	569	837	717	1019	896	904	890	615	643	548	653	934	617	530	548

Study 2

Participants

Participants were nine female and two male volunteers ranging in age from 25 to 48 years (mean age: 33.6 years). All participants were naive subjects who had not participated in Study 1.

Apparatus and Stimuli

Apparatus and stimuli were the same as in Study 1, except that auditory signals consisted of white noise.

Procedure

The procedure was similar to that of Study 1, with the following exceptions. Each participant completed twelve testing sessions which were held on consecutive days omitting weekends. An experimental session consisted of one block of temporal discrimination in the range of milliseconds and one block of duration discrimination in the range of seconds. The order of blocks was counterbalanced across participants. Each block consisted of 32 trials, and each trial consisted of two stimuli, one constant standard interval and a variable comparison interval.

The weighted up-down method was used to determine the 75%-difference threshold as an indicator of performance. For temporal discrimination in the range of milliseconds, the base duration of the standard interval was 50 ms and the initial value of the comparison interval was 75 ms. After each correct response, the duration of the comparison interval was made more similar to that of the standard interval by a factor of X, and after each incorrect response, the duration of the comparison interval was made more different than the standard interval by a factor of 3X. Thus, with the weighted up-down method a basic step size of S = 12 ms resulted in a downward step of S_{down} = 3 ms and an upward step of S_{up} = 9 ms. The duration of the comparison intervals changed with a basic step size of S = 12 ms for Trials 1-6 and S = 8 ms for Trials 7-32. For temporal discrimination in the range of seconds, the standard interval was 1,000 ms and the initial value of the comparison interval was 1,400 ms. The duration of the comparison interval changed with a basic step size of S = 400 ms for Trials 1-6, resulting in a downward step of S_{down} = 100 ms and an upward step of S_{up} = 300 ms, and S = 100 ms for Trials 7-32, resulting in a downward step of S_{down} = 25 ms and an upward step of S_{up} = 75 ms, respectively. For both tasks, order of presentation for the standard interval and the comparison interval was randomized and balanced, with each order being presented first in 50% of the trials.

Results

Individual threshold values and response times are presented in Figure 2. Cronbach's alpha for the 50- and 1,000-ms base durations were .82 and .86, respectively. As in Experiments 1A and 1B, a high level of internal consistency could also be shown for response times; alpha coefficients were .96 and .97 for the 50- and 1,000-ms base-duration blocks, respectively.

Table 2. Threshold estimates (TE) and response times (RT) 50- and 1,000-ms base durations.

Participant		Session number											
		1	2	3	4	5	6	7	8	9	10	11	12
50-ms base duration													
1	TE	3.5	8.9	3.8	5.7	5.5	8.4	9.8	2.2	5.1	7.5	5.1	5.5
	RT	1225	828	689	640	740	637	589	725	762	650	567	549
2	TE	13.4	9.0	9.2	7.6	8.3	6.7	8.6	5.7	10.0	6.7	5.2	5.7
	RT	1028	870	730	772	1061	1084	910	904	786	952	857	900
3	TE	14.6	10.4	8.9	8.3	6.9	8.4	6.1	11.1	4.3	5.7	7.2	7.4
	RT	2215	870	1849	2489	1491	1563	1400	1247	1613	1270	1001	1169
4	TE	8.6	3.3	5.5	5.8	5.6	3.7	4.8	4.4	5.5	3.0	4.1	5.7
	RT	1642	1623	1518	1371	1120	1535	1424	1091	1066	938	895	879
5	TE	10.2	8.3	7.3	9.6	8.2	5.2	6.8	5.7	11.0	5.8	3.4	3.8
	RT	465	766	525	513	794	556	571	576	508	516	846	470
6	TE	2.8	3.2	4.8	3.8	3.8	5.1	3.1	3.7	4.1	4.1	4.9	2.8
	RT	967	693	789	704	701	1088	667	548	603	572	653	446
7	TE	5.0	9.0	3.7	4.8	4.2	8.2	4.1	7.2	11.2	7.0	5.5	11.9
	RT	965	1884	1197	1793	1950	1287	1502	1099	1285	1166	1445	1303
8	TE	13.4	10.4	11.9	11.8	8.4	8.0	9.6	7.4	6.2	6.0	5.9	4.0.
	RT	1229	837	653	1168	833	997	1005	787	899	855	662	722
9	TE	10.2	13.4	7.2	7.5	5.3	8.0	3.8	7.5	5.0	4.3	7.6	8.3
	RT	1327	1468	1228	1137	1209	950	803	776	772	712	749	749
10	TE	9.0	4.5	5.2	11.0	4.8	3.5	2.7	4.4	6.9	6.0	2.8	5.4
	RT	1132	1013	956	1049	1094	975	749	663	766	1480	697	659
11	TE	16.5	10.2	13.2	16.4	6.9	7.5	6.1	5.7	6.3	5.2	5.6	6.3
	RT	811	847	739	560	586	504	420	564	614	472	563	687
1000-ms base duration													
1	TE	87	119	114	115	62	153	109	80	140	193	71	164
	RT	853	487	674	765	548	821	682	740	557	442	449	451
2	TE	223	21	194	114	139	139	164	278	173	111	143	153
	RT	639	813	628	1040	975	890	754	678	815	845	946	798
3	TE	143	148	148	89	193	103	123	80	156	106	89	213
	RT	1433	1656	2084	1176	1381	1474	1948	1804	990	868	964	1003
4	TE	64	86	75	84	45	61	71	64	89	71	40	49
	RT	1967	1084	1102	917	1088	1227	969	921	871	628	624	798
5	TE	99	41	89	54	93	62	84	56	56	77	61	55
	RT	475	490	519	810	615	416	520	622	593	516	565	493
6	TE	65	76	89	94	52	77	69	84	108	86	99	46
	RT	575	530	744	489	567	671	500	366	464	471	435	330
7	TE	163	76	74	71	118	138	57	86	30	119	74	77
	RT	636	1566	1973	2179	1601	1661	1138	1986	1575	1760	1852	2069
8	TE	102	57	79	99	96	139	72	109	128	56	79	114
	RT	555	546	775	840	644	672	758	616	708	681	726	429
9	TE	67	106	91	148	99	107	76	89	138	77	118	74
	RT	1136	1137	896	709	762	791	745	837	670	611	459	459
10	TE	143	133	183	103	13	91	213	79	61	54	84	39
	RT	898	838	786	827	728	734	704	472	619	1146	702	534
11	TE	139	139	129	139	209	183	158	144	101	189	108	75
	RT	869	506	553	536	653	475	440	490	453	378	397	459

General Discussion

The outcome of the two studies provided convincing experimental evidence that both the transformed up-down method as well as the weighted up-down method represent highly sensitive procedures for the assessment of performance on temporal discrimination and corresponding response times. The high level of internal consistency holds for filled and empty intervals as well as for 50- and 1,000-ms base durations. The high internal consistency is also supported by previous studies, in which the adaptive procedures were shown to be sensitive to individual differences in temporal-discrimination performance. In studies on personality-related differences, for example, both methods yielded results indicating differential effects of psychoticism on time estimation (e.g., Rammsayer, 2001). Also, the adaptive procedures yielded differences in temporal processing among psychiatric patients with different diagnoses (Rammsayer, 1990; Volz et al., 2001), between patients suffering from Parkinson's disease and healthy controls (Rammsayer & Classen, 1997), and between blind and sighted subjects (Rammsayer, 1994).

References

Cronbach, L. J. (1990). *Essentials of psychological testing*. New York: Harper & Row.

Derman, C. (1957). Non-parametric up-and-down experimentation. *Annals of Mathematical Statistics, 28*, 795-797.

Kaernbach, C. (1991). Simple adaptive testing with the weighted up-down method. *Perception & Psychophysics, 49*, 227-229.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *Journal of the Acoustical Society of America, 49*, 467-477.

Rammsayer, T. (1990). Temporal discrimination in schizophrenic and affective disorders: evidence for a dopamine-dependent internal clock. *International Journal of Neuroscience, 53*, 111-120.

Rammsayer, T. H. (1994). Temporal information processing in blind and sighted subjects. In L. M. Ward (Ed.) *Fechner Day 94. Proceedings of the Tenth Annual Meeting of the International Society for Psychophysics* (pp. 179-184). Vancouver, Canada: The International Society for Psychophysics.

Rammsayer, T. H. (2001). Temporal information processing and basic dimensions of personality: differential effects of psychoticism. *Personality and Individual Differences*, in press.

Rammsayer, T. & Classen, W. (1997). Impaired temporal discrimination in Parkinson's disease: temporal processing of brief durations as an indicator of degeneration of dopaminergic neurons in the basal ganglia. *International Journal of Neuroscience, 91*, 45-55.

Volz, H.-P., Nenadic, I., Gaser, C., Rammsayer, T., Häger, F. & Sauer, H. (2001). Time estimation in schizophrenia: a fMRI study at adjusted levels of difficulty. *NeuroReport, 12*, 313-316.