ASSESSMENTS OF SPATIAL TEMPORAL ORDER JUDGMENT (TOJ) THRESHOLDS USING DIFFERENT PSYCHOPHYSICAL METHODS

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Spatial TOJ measures the ability to correctly perceive the order of two tones presented to the two ears. This task has been used in both basic and applied research, testing different populations, such as dyslexic readers, aphasic patients, aging adults, and sleep deprived adults. A variety of methodologies similar to Fechner's original methods have been used, resulting in a wide range of reported TOJ thresholds. In the present study, we used three different methodologies to estimate dichotic TOJ thresholds: constant stimuli by trial (ISI randomized by trial); constant stimuli by block (ISI randomized by block) and an adaptive staircase procedure. TOJ thresholds and the inter-individual variance from the adaptive staircase procedure (Mean=44.33msec, SD=22.97msec) were very similar to those obtained using method of constant stimuli by trial (Mean=43.47, SD=24.45), and when using constant stimuli by block (Mean=41.84msec, SD=20.32msec). These results indicate the stability of the TOJ threshold across different psychophysical methods.

Temporal order judgment (TOJ) refers to the ability to correctly perceive the temporal order of at least two stimuli. The study of the human capacity to judge the temporal order of two stimuli became popular with the classic work of Hirsh (1959) and Hirsh and Sherrick (1961). The general understanding of the meaning of temporal order is that it represents a measure of the perception of the temporal relationships of two or more stimuli, and is therefore, a fairly basic indicator, or marker, of "temporality".

Recently, spatial TOJ, in which the tones to be judged differ in the ear they are presented to, has become a popular tool for measuring temporal processing in a variety of populations, among whom are: 1) aphasic patients (von Steinbuchel, Wittmann, Strasburger, & Szelag, 1999; Fink et al., 2006); 2) dyslexic readers (Ben-Artzi et al., 2005; Fostick, Bar-El, Ben-Artzi, Babkoff, 2008; Fostick and Zukerman, 2010; Reed, 1989; Tallal, 1980); 3) sleep deprived young adults (Babkoff et al., 2005; Fostick and Zukerman, 2010); and 4) elderly adults (Fink et al., 2005; Fitzgibbons and Gordon-Salant, 1998; Fostick, Ben-Artzi, Babkoff, 2007; Fostick and Zukerman, 2010; Szymaszek et al., 2006, 2009). One of the problems with comparing TOJ thresholds of sub-populations is that the thresholds reported for the control groups (young healthy adults) vary by fairly large amounts across studies (Table 1). The broad range of TOJ thresholds may be explained by several factors: (1) different stimuli used by different researchers (broad band clicks versus tones); (2) different stimulus durations (5-40 msec duration tones and 1 msec clicks); and (3) different methodologies.

The purpose of the current study was, therefore, to test whether the source of the large variability in TOJ thresholds can be ascribed to differences in the methodologies used by the different researchers. We measured spatial TOJ thresholds while controlling for stimulus characteristics (same tone frequency and same duration) and only manipulating the methodology of measurement. We compared TOJ thresholds using three different methodologies for the same participants, with the same stimuli (pure tones), frequency (1kHz), and duration (15 msec): (1) adaptive staircase procedure, starting with a long inter-stimulus interval (ISI= 240 msec) that increase or decrease dependent upon the participants' responses; (2) method of constant stimuli, with ISI values that are defined prior to the experiment, and are presented randomly at each trial (method of constant stimuli by trial); and (3) method of constant stimuli, with ISI values that are defined prior to the experiment, but are presented in blocks of the same ISI values (method of constant stimuli by block).

Table 1. TOJ thresholds reported in the literature

Study	Stimuli	N	Age	ISI Threshold (in msec)
Staircase Adaptive Procedure				
Lotze et al. (1999)	1 ms clicks	5	24 to 30	37
Lotze et al. (1999)	1 ms clicks	5	24 to29	21
Lotze et al. (1999)	1 ms clicks	2	27 to 31	24
Szymaszek et al. (2006, 2009)	1 ms clicks	17	20 to 19	68
Fink et al. (2005)	1 ms clicks	20	20 to 35	50
Von Steinbuchel et al. (1999)	1 ms clicks	17	50	58
Method of Limits				
Kinsbourne et al. (1991)	1 ms clicks	21	27	47
Constant Stimuli by Trial				
Fostick et al. (2010)	15 ms 1.8kHz tones	18	20 to 35	60
Fostick et al. (2011)	5 ms 1kHz tones	28	25	114
Fostick et al. (2011)	10 ms 1kHz tones	28	25	97
Fostick et al. (2011)	20 ms 1kHz tones	28	25	79
Fostick et al. (2011)	30 ms 1kHz tones	28	25	57
Fostick et al. (2011)	40 ms 1kHz tones	28	25	42
Kolodziejczyk & Szelag (2008)	15 ms 300 Hz tones	17	19 to 25	37
Babkoff et al. (2005)	10 ms 1 and 1.5kHz tones	18	24	63
Ben-Artzi et al. (2005)	15 ms 300Hz and 600Hz tones	26	20-26	49

Method

Participants. Seventeen female students (age 21 to 24) participated in the study. All were screened for normal hearing and were native Hebrew speakers.

Spatial TOJ. Pairs of 15 msec pure tones (1kHz) were presented dichotically (one to each ear) at 40 dB HL, and with 1 msec rise/fall time. Participants were required to reproduce the order in which they heard the tones (left ear first then right ear, or the reverse). Half of the trials were presented with an order of left ear first then right ear, and the reverse in the other half. In the constant stimuli method, tones were presented with an ISI of 5, 10, 15, 30, 60, 90, 120, and 240 msec. Each ISI value was repeated 16 times, resulting in 256 trials (2 tone orders x 8 ISIs x 16 trials). In the constant stimuli by trial method, ISI values were presented randomly with a short recess after every 32 trails. In the constant stimuli by block version, ISI values were presented in blocks, with a short recess after every block. In the adaptive staircase procedure, tones were presented in a random order using a two alternative forced choice 2-down-1-up adaptive staircase procedure, with initial ISI of 240 msec. The experiment was terminated after 10 reversals, and the threshold was calculated as the average of the last eight reversals. The order of testing the three methodologies was counterbalanced between participants and was done in a single session of up to 30 minutes. Prior to the first task, participants underwent four-phases of training as described in Ben-Artzi et al. (2005).

Results

Figure 1 presents ISI thresholds for each spatial TOJ version. Similar ISI thresholds were found for staircase adaptive procedure (Mean=44.33msec, SD=22.97msec), constant stimuli by trial (Mean=43.47, SD=24.45), and constant stimuli by block (Mean=41.84msec, SD=20.32msec). Repeated measures ANOVA, with task version as a within subjects variable, revealed no significant difference between the tasks' thresholds ($F_{(2,32)}$=.172, p>.05).

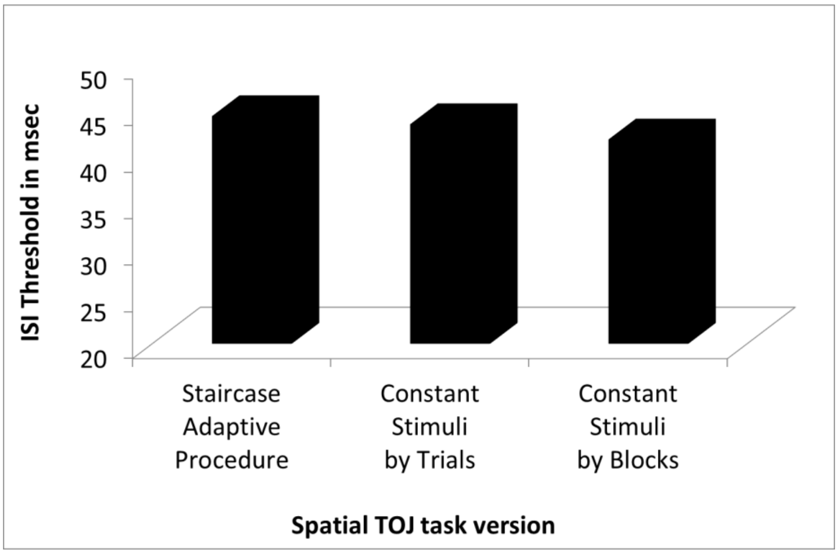

Figure 1. Mean ISI thresholds for spatial TOJ task versions

Discussion

The seventeen spatial TOJ thresholds for normal young participants reported in the recent literature and included in Table 1 range from 21- 114 msec and average 56.06 msec interstimulus interval (ISI). However, with a standard deviation of 23.923 and a coefficient of variation of .427, the expected average thresholds of control populations in studies of spatial TOJ may cause difficulties in finding valid and reliable results. We suggested that the broad range of spatial TOJ thresholds may have resulted from one or several factors, related to differences in stimulus parameters used by the different researchers or differences in measurement methodologies. In the current study we examined the possibility that the large variability may be due to differences in methodologies of measurement. We assessed spatial TOJ thresholds in the same participants, with the same stimulus parameters (15-msec duration, 1kHz pure tones), but with three different methodologies: 1) staircase adaptive procedure; 2) method of constant stimulus, with ISI manipulated by trial; and 3) method of constant stimulus with ISI manipulated by block. We found almost the exact same thresholds with all three procedures. Moreover, we found no difference in the variability of thresholds (standard deviations) among the three methodologies. These findings suggest that the wide range of TOJ thresholds reported in the literature are not due to differences in methodology, but may be the result of differences in the stimulus characteristics across the different studies.

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