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The relationship between lateral differences in tympanic membrane temperature and behavioral impulsivity

William S. Helton *

Department of Psychology, University of Canterbury, Private Bag 4800, Christchurch, New Zealand

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ABSTRACT

In this study lateral differences in tympanic membrane temperature (T_{Ty}) were explored as a correlate of either impulsive or cautious responding in Go–No-Go tasks. Thirty-two women and men performed two sustained attention to response tasks (Go–No-Go tasks). Those with warmer right in comparison to left tympanic membranes were more cautious, and those with warmer left in comparison to right tympanic membranes were more impulsive. This finding is in line with previous research and theory indicating a hemispheric bias for active and passive behavior. T_{Ty} may be a useful addition to the techniques employed by neuropsychologists.

1. Introduction

Tympanic membrane temperature (T_{Ty}) may be a useful physiological metric for scientists and clinicians interested in the relationships between brain laterality and behavior. T_{Ty} has been used recently as a non-invasive and inexpensive indicator of lateralized changes in cerebral blood flow during cognitive tasks (Cherbuin & Brinkman, 2004, 2007; Helton, Hayrynen, & Schaeffer, 2009; Helton, Kern, & Walker, 2009; Hopkins & Fowler, 1998). Changes in cerebral blood flow influence tympanic membrane blood perfusion and temperature (Sukstanskii & Yablonskiy, 2006). A source of confusion in the literature, however, regarding tympanic temperature is the distinction between differences in T_{Ty} *between-subjects* and difference in T_{Ty} *within-subjects*.

As discussed by Zelenski and Larsen (2000), relationships can be within-subjects or between-subjects and these represent state or trait relationships respectively. Within-subject relationships are accounted by differences between states over time or over measurement occasions. These relationships essentially remove between-subjects variance by estimating change within-subjects, for example, from a control or resting baseline. The state information is hopefully not confounded by individual differences, as the initial individual differences between-subjects are held constant. The person essentially serves as their own control. Under normothermic circumstances the brain is warmer than the incoming blood as the brain is both metabolically active and well insulated from the environment inside the enclosed skull. An increase of blood flow from the relatively cooler body reduces T_{Ty} relative to a baseline measure, whereas a decrease in blood flow from the body elevates T_{Ty} relative to a baseline measure. In studies focusing on within-subjects changes (for example Cherbuin & Brinkman, 2004, 2007; Helton, Hayrynen, et al., 2009; Helton, Kern, et al., 2009; Hopkins & Fowler, 1998), therefore increased T_{Ty} relative to a resting baseline measure is a marker of reduced cerebral blood flow and decreased T_{Ty} is a marker of increased cerebral blood flow.

Between-subjects relationships, however, represent differences between individuals' average levels on the measure, or trait differences. These relationships are calculated by collapsing the individuals' data over time (e.g. averaging within-subjects), thus eliminating variance due to states (or within-subjects differences). While changes in T_{Ty} from baseline recordings, within-subjects differences, may reflect changes in cortical activation during tasks, consistent between—subjects differences of right and left T_{Ty} may reflect underlying differences in cerebral lateralization amongst individuals due to trait differences (Boyce et al., 2002). Since the brain is well insulated from the environment, a relative difference in residual heat buildup would occur if there is a consistent difference in lateral metabolic cerebral activity. In between-subjects studies a consistent lateralized heat buildup should be reflected in average ipsilateral T_{Ty}.

A consistent elevated temperature in one tympanum or the other may, therefore, reflect overall greater resting or residual activation in the ipsilateral hemisphere; cortical temperature is highly correlated with T_{Ty} in the ipsilateral ear (Mariak, White, Lyson, & Lewko, 2003; Schuman et al., 1999). Indeed Boyce et al. (2002) demonstrated that warmer left T_{Ty} was associated with approach behavior, whereas warmer right T_{Ty} was associated with passive behavior in children. In general, active states lead to greater left

* Fax: +64 3 3642181.
E-mail address: wshelton@mtu.edu

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hemisphere activation and passive states lead to greater right hemisphere activation (Davidson, 2000; Gray, 2001; Harmon-Jones & Allen, 1998; Sutton & Davidson, 1997). Originally this lateral asymmetry was framed as reflecting a difference in motivational direction between the hemispheres: approach versus withdrawal. More recent work has instead framed this distinction not in terms of motivation direction, but in terms of activation–inhibition, with left hemisphere activation reflecting active, impulsive or risk-taking behavior and right hemisphere activation reflecting passive, cautious or inhibitory behavior (Clark, Manes, Antoun, Sahakian, & Robbins, 2003; Drake & Myers, 2006; Fecteau et al., 2007; Gianotti et al., 2009; Knoch et al., 2006; Miller & Milner, 1985; Wacker, Chavanon, Leue, & Stemmler, 2008; Xue, Aron, & Poldrack, 2008). Depressed mothers and their offspring, for example, have greater right hemisphere EEG activity than non-depressed controls (Diego, Jones, & Field, 2010) and patients with right hemisphere lesions prefer risky decisions (Clark et al., 2003).

Given the lateralization of active–impulsive and passive-cautious states, adults with relatively greater left hemisphere activation and thus relatively elevated left T_{Ty} should be more impulsive (active). This should be the case when examined with averaged T_{Ty} as this measure should reflect consistent between-subjects differences in left lateral activation. If a person has a consistent left hemisphere activation bias there should be an increased heat buildup reflected in the person's left T_{Ty}. Individuals with relatively greater right hemisphere activation and thus elevated right T_{Ty} should instead be more cautious. If a person has a consistent right hemisphere activation bias there should be an increased heat buildup reflected in the person's right T_{Ty}. In the present study, this was investigated by examining the association between lateral differences in T_{Ty} and performance on the sustained attention to response task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). SARTs require participants to trade-off the speed of a Go response with accuracy in withholding to No-Go stimuli. The faster one responds to the Go stimuli, the more likely one is to press inappropriately to the No-Go stimuli (Helton, 2009). The SART, therefore, provides an excellent means to test the association between lateral differences in T_{Ty} and the behavioral continuum between impulsive and cautious. People with relatively elevated left T_{Ty} should make faster responses to the Go stimuli but also make more errors of commission than people with relatively elevated right T_{Ty}.

2. Method

This study was designed to examine both the association between consistent T_{Ty} lateral differences and behavioral impulsivity, and task induced changes in T_{Ty}. The task induced changes of lateral T_{Ty} are summarized elsewhere (see Helton, Kern, et al., 2009); this report focuses solely on the association between lateral T_{Ty} differences and behavioral impulsivity. Hence, an abbreviated description of the experimental procedures and task are produced here.

2.1. Participants

Thirty-two undergraduate students (18 men and 14 women) from introductory psychology classes at a university served as participants for course credit. All of the participants had normal or corrected-to-normal vision and were right-handed as indexed by a +75 or greater score on the Edinburgh Handedness Inventory (Oldfield, 1971). Participants ranged in age between 18 and 32 years (M = 19.97 years, SD = 2.58).

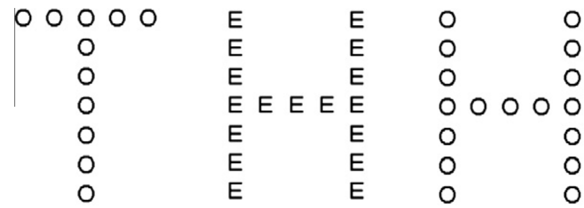

Fig. 1. The stimuli (target, T_O, and distracters, H_E and H_O) used in the present experiment.

2.2. Procedure

The participants were tested individually in a small laboratory room. Participants were seated in front of a blank video display screen for 4 min. Three baseline temperature recordings were made in each ear (the order of ear measurement, which ear was measured first, was randomized for each participant) after the 4 min period. After the first ear was determined randomly the measures were alternated between the two ears. All temperature recording were made by inserting a Braun Thermoscan® ear thermometer into the auditory canal of the participant. All measurements were made in concordance with the manufacturer's recommendations. The temperature reading was sensitive to 0.1 °C. The same experimenter performed all the temperature measurements on all participants to reduce any differences due to experimenter individual differences (Helton & Carter, in press). As the tympanic membrane is hotter than the surrounding ear tissue the highest of the three measurements was recorded (Heusch, Suresh, & McCarthy, 2006).

After the baseline period, participants performed a SART detection task twice (see Helton, Kern, et al., 2009). The SART task employed in this study has been used previously and is challenging (Helton, 2009). In the SART participants inspected the repetitive presentation of global capital letters composed of solid smaller black capital letters. The letter stimuli consisted of either a capital H or T composed of smaller capital Es or Os. In the task, the assignment was to withhold responses to H_O targets (No-Go) and respond to H_E and T_O distracters (Go). See Fig. 1 for examples of the SART stimuli. Three different font sizes of the local elements were employed randomly (12pt, 14pt, and 16pt). The global figures ranged in size between 50 mm × 70 mm and 60 mm × 95 mm. The Go and No-Go stimuli were presented at random; No-Go stimuli occurred with a probability p = .13 and the Go stimuli occurred with a probability of p = .87. Letter stimuli were presented for 100 ms and then were masked for 1340 ms during which a response could be recorded. The mask was a solid black rectangle (85 mm × 110 mm). Participants signified their detection of critical signals by pressing a key labeled "SIG" on an electronic response pad located in front of them. There were approximately 42 stimuli events per minute and the SART was 5.54 min in duration each. The participants were provided with 5.54 min of practice with the task prior to the start of each of the two test tasks, as the task is challenging (Helton, 2009). Immediately after completing each SART, three T_{Ty} measures were taken for each ear as performed after the baseline period. There was a 2 min rest period between test tasks.

3. Results

The left T_{Ty} were subtracted from right T_{Ty} respectively for each of the three measurement periods (baseline, post-task 1, and post-task 2): ΔT_{Ty} = Right T_{Ty}–Left T_{Ty}. These three ΔT_{Ty} were averaged to create an average ΔT_{Ty}. The three period ΔT_{Ty} s did inter-correlate (rs = .39–.59), demonstrating inter-individual consistency across