Psychophysiology, 47 (2010), 979–983. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/j.1469-8986.2010.00999.x

BRIEF REPORT

Line bisection as a neural marker of approach motivation

KYLE NASH,[a] IAN McGREGOR,[a] AND MICHAEL INZLICHT[b]

[a]Department of Psychology, York University, Toronto, Ontario, Canada
[b]Department of Psychology, University of Toronto Scarborough, Toronto, Ontario, Canada

Abstract

Approach motivation has been reliably associated with relative left prefrontal brain activity as measured with electroencephalography (EEG). Motivation researchers have increasingly used the line bisection task, a behavioral measure of relative cerebral asymmetry, as a neural index of approach motivation-related processes. Despite its wide adoption, however, the line bisection task has not been confirmed as a valid measure of the precise pattern of activity linked to approach motivation. In two studies, we demonstrate that line bisection bias is specifically related to baseline, approach-related, prefrontal EEG alpha asymmetry (Study 1) and is heightened by the same situational factors that heighten the same approach-related prefrontal EEG alpha asymmetry (Study 2). Results support the line bisection task as an efficient and unobtrusive behavioral neuroscience measure of approach motivation.

Descriptors: Line bisection, Approach motivation, Frontal alpha asymmetry

The *line bisection task* is a widely used behavioral measure of relative cerebral hemisphericity (Jewell & McCourt, 2000). In this task, participants are asked to indicate the perceived midpoint of a number of horizontal lines. Tendencies toward rightward versus leftward errors in estimating the actual midpoints are taken to reflect relative primacy of right versus left visual fields, respectively, and neural activity in the contralateral hemisphere (Milner, Brechmann, & Pagliarini, 1992). Although developed as a clinical measure of visual neglect, researchers have increasingly used it as a general marker of dispositional or situational hemisphericity. Relative left prefrontal activity, as assessed by electroencephalography (EEG), is reliably associated with approach-motivation (Harmon-Jones, 2003; Harmon-Jones & Allen, 1998), thus the line bisection task has often been used to index phenomena related to approach-motivation. For example, action-related emotions (Drake & Myers, 2006), writing about cherished values (Shrira & Martin, 2005), monosemantic processing (Baumann, Kuhl, & Kazén, 2005), and narrowed attention (Förster, Liberman, & Kuschel, 2008; see Gable & Harmon-Jones, 2008) are all approach-related phenomena that have been associated with a rightward line bisection bias, indicative of left hemisphericity.

Surprisingly, however, this task has never been validated as a measure of prefrontal asymmetry associated with approach motivation. That is, despite its wide adoption by motivation researchers, the link between EEG prefrontal activity and line bisection bias has yet to be directly demonstrated. In fact, previous research suggests line bisection bias may be more a marker of parietal than prefrontal function (Vallar & Perani, 1986). However, in light of recent work implicating the dorsolateral prefrontal cortex in both visual processing and approach motivation, the present research was conducted to provide much needed validation for the line bisection task as an index of prefrontal asymmetry.

Visual Processing and Frontal Cortex

Parietal and frontal brain areas in the monkey share extensive and direct linkages (Morecraft, Geula, & Mesulam, 1993) and in humans these areas are quite often coactive during various visual tasks, as measured with fMRI (Husain & Nachev, 2007). In a recent study, parietal-frontal pathways were directly manipulated through electrical stimulation that deactivates discrete brain areas during brain tumor surgery in two conscious patients with right-hemisphere gliomas (de Schotten, Urbanski, Duffau, Volle, Lévy, et al., 2005). During removal of the tumor, researchers found the most rightward line bisection bias after deactivation of a subcortical parietal-frontal pathway (de Schotten et al., 2005), which originates in the inferior parietal lobe and the occipito-parietal area and connects to the dorsolateral prefrontal cortex (this pathway is identified as the human homologue of the second branch of the *superior longitudinal fasciculus* described in the monkey brain, see Schmahmann et al., 2007). These results demonstrate that parietal-frontal interaction is necessary for symmetrical visual processing and the frontal component can be identified as the dorsolateral prefrontal cortex (de Schotten et al., 2005). Importantly, the dorsolateral prefrontal cortex is the brain area specifically linked to approach motivation-related frontal asymmetry.

Frontal EEG Asymmetry and Approach Motivation

A substantial literature demonstrates frontal EEG asymmetry as an important neural marker of various emotional, motivational,

Address reprint requests to: Kyle Nash, Behavioural Sciences Building, York University, 4700 Keele Street, Toronto, ON, M3J 1P3, Canada. E-mail: nashka@yorku.ca

and psychopathological constructs (Elliot, 2008). Researchers have consequently sought to characterize the differential role that the right and the left prefrontal cortex may play in these experiences, and the emergent literature now strongly supports a link between greater left prefrontal activity and approach motivation. For example, greater left-than-right frontal baseline activity has been related to (a) dispositional measures of approach motivation, such as behavioral activation system and promotion focus orientations (Amodio, Shah, Sigelman, Brazy, & Harmon-Jones, 2004; Harmon-Jones & Allen, 1997); (b) measures of approach-related emotion, such as positive affect and anger (Harmon-Jones & Allen, 1998; Tomarken, Davidson, Wheeler, & Doss, 1992); and (c) psychopathologies related to approach motivation, such as manic phases of bipolar disorder (Harmon-Jones, Abramason, Siegelman, Bohlig, Hogan, et al., 2002). Further supporting this association between left prefrontal activity and approach motivation, frontal asymmetry is thought to arise due to different signalling strength from the reward-related dopaminergic pathway to the frontal cortices (Berridge, Espana, & Stalnaker, 2003). Moreover, source localization has found that frontal EEG asymmetry linked to approach motivation specifically indicates dorsolateral prefrontal cortex activity (Pizzagalli, Sherwood, Henriques, & Davidson, 2005).

Current Studies

Line bisection bias and approach motivation implicate the same cortical area; namely, the dorsolateral prefrontal cortex. This suggests that line bisection bias could potentially index approach-related brain activity. The line bisection task would have a considerable pragmatic advantage over EEG if demonstrated as a valid marker of left prefrontal asymmetry. It is far less invasive and total assessment time is a few minutes as compared to an hour or more. In addition to bringing pragmatic benefits for future research, EEG corroboration of the line bisection task would retrospectively validate the large body of motivation-related line bisection research previously conducted. The goal of the present research, therefore, is to validate the line bisection task based on EEG asymmetry. In Study 1, we assess dispositional links between line bisection bias and relative left prefrontal EEG neural activity. In Study 2, we directly replicate previous research on state EEG asymmetry using the line bisection task.

Study 1

In a single session, we measured both line bisection bias and relative asymmetry, as assessed by EEG, at all homologous EEG sites. We hypothesized that line bisection bias would be related to relative left prefrontal activity from the frontal homologous nodes F7 and F8, which sit over dorsolateral left and right prefrontal cortices, respectively.

Method

EEG Recording and Processing

Thirty-six right-handed, University of Toronto Scarborough psychology students were recorded for eight 1-min intervals of continuous EEG (4 eyes open, 4 eyes closed). Data from 29 (21 female) remained for analyses after exclusions due to malfunctioning equipment ($n = 2$), EEG outliers ($n = 3$), or excessive artefacts ($n = 2$). EEG and right-eye vertical electrooculogram (VEOG) was digitized at 560 Hz with average ear reference and forehead ground. Recordings were collected from 32 electrode sites according to the 10–20 system with a bandpass filter at 0.1–100 Hz and a notch filter at 60 Hz. Electrode impedances were kept below 5 kΩ. The continuous EEG recordings were corrected off-line for eye-blinks using the VEOG channel and the second order blind identification (SOBI) procedure, which is a signal processing method for isolating and removing ocular artifacts (Tang, Liu, & Sutherland, 2005), and movement artifacts were automatically detected with a -75 μV and $+75$ μV threshold.

Contiguous artefact-free epochs of 2.048 s from each 1-min interval were extracted through a Hamming window and overlapped by 75% to minimize data loss. Power spectra were calculated via fast Fourier transform. Power values (in μV^2) were averaged across epochs within each interval. Total power within the alpha band (8–13 Hz), an inverse indication of cortical activity, was logarithmically transformed, and asymmetry scores were calculated as right-site minus homologous left-site log alpha power for all homologous pairs (F8-F7, F4-F3, P8-P7, P4-P3, FP2-FP1, FC2-FC1, FC6-FC5, C4-C3, CP6-CP5, CP2-CP1, T8-T7, O2-O1). Higher scores indicate relatively greater left-than-right cortical activation. The eight minute intervals for the F8-F7 alpha score were entered in a reliability analysis and demonstrated a satisfactory Cronbach alpha coefficient of .91.

Line Bisection

After EEG recording, participants completed the line bisection task by marking the perceived center point of 14 staggered horizontal lines, each approximately 23 centimeters long, presented on a landscaped-view sheet of paper. The distance from each line's true midpoint was measured in millimeters and leftward errors were scored as negative values. A mean line bisection score was calculated by averaging the scores across the 14 lines. Positive values indicated relatively greater left-than-right hemispheric activation. Reliability analysis of the 14 lines also demonstrated an acceptable Cronbach alpha coefficient of .84.

Results and Discussion

Consistent with the bulk of previous research on neurologically normal, right-handed individuals (Jewell & McCourt, 2000), the participants of this study also demonstrated a slight overall tendency towards leftward line bisection ($M = -1.45$, $SD = 4.82$). Thus, any associations between line bisection bias and EEG asymmetry would be difficult to attribute to potential population irregularities. To test our hypothesis that bisection bias would be specifically related to relative left prefrontal activity, participants' line bisection scores were then correlated separately with the alpha asymmetry scores at each electrode site. As seen in Table 1 and Figure 1, bisection bias was positively related to relative left prefrontal activity, as measured with the F8-F7 alpha EEG score ($M = .10$, $SD = .20$), $r = .38$, $p < .05$; the greater the left prefrontal activity at F8-F7, the greater the rightward bias on the line-bisection task. None of the correlations at the other electrodes sites were significant (see Table 1, ps $> .16$). However, the next strongest correlation with bisection bias, the P8-P7 alpha EEG score ($M = .22$, $SD = .64$), $r = .26$, was in the same direction as the F8-F7 score. Although not significant, this is consistent with parietal-frontal interaction in visual processing outlined above.

In sum, results indicate that the specific pattern of left prefrontal activity that has reliably been associated with approach motivation (e.g., Harmon-Jones, 2003) is also significantly related to line bisection bias. However, this study reflects dispositional evidence. Study 2 was thus conducted to examine situational approach motivation.

Table 1. *Correlations Between Line Bisection and Relative Left EEG Scores*

	F8-F7	F4-F3	P8-P7	P4-P3	FP2-FP1	FC2-FC1	FC6-FC5	C4-C3	CP6-CP5	CP2-CP1	T8-T7	O2-O1
Line bisection: (left hemisphericity)	0.38*	0.04	0.26	0.13	– 0.10	– 0.07	0.22	0.13	0.19	– 0.02	0.20	– 0.19

Note: $*p < < .05$.

Study 2

In previous research, we demonstrated that high self-esteem (HSE) individuals are inclined towards approach motivation and respond to a challenging event with situational approach motivation, including the F8-F7 alpha EEG score from Study 1 (McGregor, Gailliot, Vasquez, & Nash, 2007; McGregor, Nash, & Inzlicht, 2009). Directly replicating this prior EEG finding, but with the line bisection task, would provide a rigorous demonstration that line bisection bias is sensitive to state neural approach motivation. Based on Study 1, which demonstrated that rightward bisection bias is related to F8-F7 alpha EEG activity, we hypothesized that HSE individuals should respond to a similar challenge manipulation with a shift in rightward bisection bias (i.e., left hemisphericity).

Method

Self-Esteem, Challenge Manipulation, and Line Bisection

Twenty-nine participants (25 female) from a York University undergraduate psychology class first filled out a 10-item self-esteem scale (Rosenberg, 1965) that included items such as, "I take a positive attitude toward myself," "I am able to do things as well as most other people," and "I feel I do not have much to be proud of" (reverse scored). They then completed a pre-challenge line bisection task, using the same materials as in Study 1. This measure was used as a covariate to reduce error variance in the main analyses.

Next, participants were randomly assigned to either the Challenge or No-Challenge conditions. In the Challenge condition, participants nominated and described a complex academic dilemma that they currently faced. The No-Challenge condition involved the same task except about a friend's academic dilemma with no bearing on the participant's own situation. The Challenge condition has caused HSEs to respond with approach-motivated conviction (McGregor & Marigold, 2003) and is conceptually similar to the academic challenge manipulation that caused HSEs to respond with increased F8-F7 alpha EEG score (McGregor et al., 2009).

Finally, the post-challenge line bisection task was administered. For both the pre- and post-challenge line bisections, the same scoring method was used as in Study 1, Reliability analyses of both pre- and post-challenge line bisection again demonstrated acceptable Cronbach alpha coefficients of .81 and .82, respectively.

Results and Discussion

Regression of bisection bias on Challenge, Self-Esteem, and the Challenge × Self-Esteem interaction (with baseline bisection bias as a covariate) demonstrated the predicted interaction effect, $t(24) = 2.21$, $p < .05$, with the highest bisection bias among those in the Challenge condition with HSE (see Figure 2). Simple effect analyses showed that rightward bisection bias was highest at HSE (+1 SD) in the Challenge condition ($y' = 2.17$)—significantly higher than in the No-Challenge condition ($y' = -1.65$), $t(24) = 3.05$, $p < .01$.

This study shows that only HSE individuals in the Challenge condition responded with increased rightward bisection bias. These results mirror previous results from the same study design but with F8-F7 alpha EEG activity (McGregor et al., 2009), supporting our contention that the line bisection can index situational changes in approach-related neural activity.

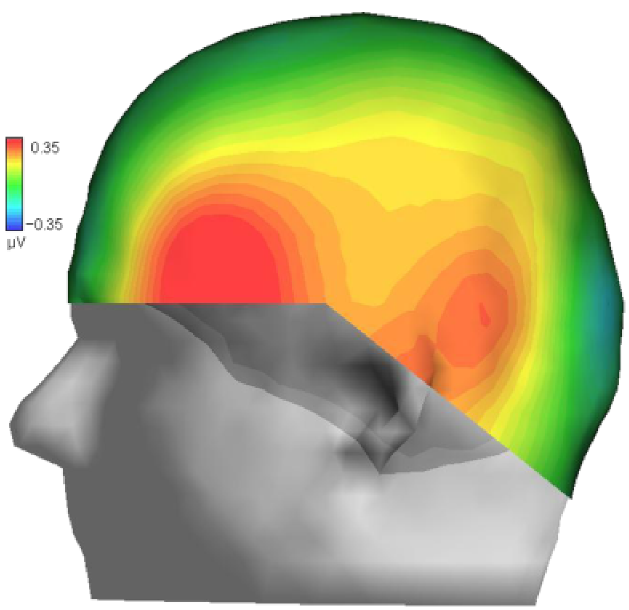

Figure 1. Correlations between line bisection bias (left hemisphericity) and relative left EEG activity.

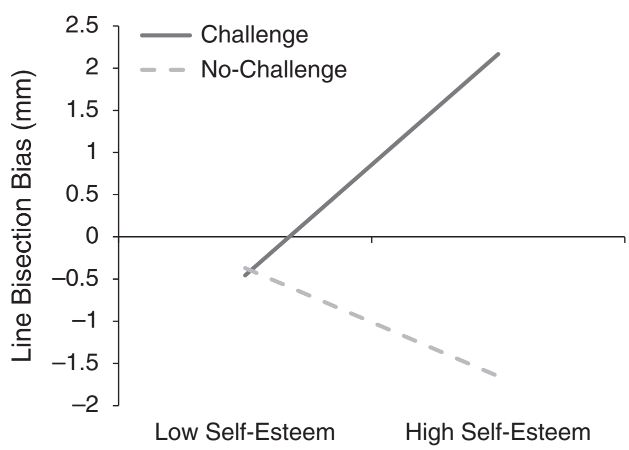

Figure 2. Line bisection bias (left hemisphericity) as a function of Self-Esteem and Challenge.

Conclusion

Although use of the line-bisection as a marker of approach motivation has been increasing in recent years (e.g., Drake & Myers, 2006; Friedman & Förster, 2005), we believe that Study 1 provided the first direct evidence that this task actually predicts resting left prefrontal alpha asymmetry. Study 2 replicated previous state-related EEG findings but with the line bisection task, demonstrating this task is also sensitive to situational approach-related neural activity. Importantly, the F7/F8 nodes used to compute EEG alpha asymmetry lie directly over the dorsolateral prefrontal cortex, a cortical area implicated in both symmetrical visual processing and approach motivation. Thus, these results support the simple and non-invasive line bisection task as a neural index of approach motivation and asymmetrical activity related to the dorsolateral prefrontal cortex.

We do note certain limitations. Resting EEG alpha asymmetry is known to partially reflect state-related factors, not just dispositional asymmetry (see Hagemann, 2004). Additionally, the moderate effect in Study 1, while an important observation, suggests the line bisection task may not unerringly index variance in left dorsolateral prefrontal cortex activity. We encourage direct manipulations of approach motivation and measures of EEG and line bisection in subsequent research to bolster the findings presented here.

However, in settings where EEG may not be feasible, we conclude that line bisection holds further promise as an efficient and unobtrusive alternative for motivational researchers. A wide array of approach motivation-related phenomena—such as promotion-focus (Amodio et al., 2004; Higgins, 1997), positive affect (Tomarken et al., 1992), power (Keltner, Gruenfeld, & Anderson, 2003), conviction (McGregor, 2006), anger and dissonance reduction (Harmon-Jones, 2004; Harmon-Jones, Peterson, Gable, & Harmon-Jones, 2008)—could potentially be more readily researched with the simple line bisection task.

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(Received April 9, 2009; Accepted October 5, 2009)