



# Cognitive consequences of individual differences in arousal asymmetry



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## ABSTRACT

Prior research has demonstrated that semantic organization in the right hemisphere (RH) is more diffuse and specialized for distant semantic associates than is semantic organization in the left hemisphere (LH). The present research explored individual differences in this regard. If the RH is more specialized for distant semantic associates, then individuals with a more active RH should display greater activation of distant semantic associations. Two experiments were conducted to examine this issue. In both studies a line bisection task was used to assess arousal asymmetry. In Experiment 1, greater RH activation was associated with the ability to generate remote associates to three word stimuli. In Experiment 2, relatively greater RH activation was associated with enhanced priming of distant semantic associates. Taken together, these experiments demonstrate that arousal asymmetry is an individual difference variable that is related to variability in semantic organization and retrieval.

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## 1. Introduction

The two hemispheres of the brain are specialized for different functions. For example, performance on a lateralized word recognition task tends to be superior for the left hemisphere (LH) relative to the right hemisphere (RH). In addition to hemispheric functional differentiation, however, there also appear to be individual differences in arousal asymmetry (Levy, Heller, Banich, & Burton, 1983), that is, greater tonic activation of one hemisphere relative to the other. Several lines of research suggest that are different cognitive and emotional tendencies associated with the two hemispheres. Research on hemisphericity, for example, has demonstrated trait-like preferences for different cognitive modes that are associated with each of the two cerebral hemispheres, and that hemispheric preference can be reliably identified via performance on a variety of biophysical tasks (Morton, 2001, 2002, 2003). Moreover, hemispheric preference is related to variability in Corpus Callosum size with right brain oriented individuals having substantially larger CCs than left brain oriented individuals (Morton & Rafto, 2006). Other researchers have focused on some of the emotional concomitants of arousal asymmetry (Sutton & Davidson, 1997; Wheeler, Davidson, & Tomarken, 1993), demonstrating, for example, an association between LH activation and positive mood. The present research contributes to these lines of inquiry by examining some of the cognitive consequences of individual differences in arousal asymmetry.

## 2. Hemispheric specialization, semantic priming, and creativity

The present approach builds upon research demonstrating hemispheric functional differences in semantic representation and retrieval. One of the earliest and most common techniques for demonstrating hemispheric differences in semantic organization involved semantic priming. In these studies semantic priming was found to be roughly equivalent in the two hemispheres when activation was relatively automatic (short stimulus onset asynchrony (SOA), masked primes, etc., Neely, 1991) and the prime target pairs were strongly related and members of the same semantic category (e.g., sofa–chair) (Chiarello, Burgess, Richards, & Pollock, 1990; Richards & Chiarello, 1995). However, when the stimuli were not associated or weakly associated category members (e.g., lamp–chair), priming tended to occur only in the RH and not in the LH (Chiarello, 1985; Chiarello et al., 1990, 1996).

These findings suggest that there is passive activation of weakly related category members within the right but not the left hemisphere (Chiarello, 1998). Further support for this idea was provided by Beeman and colleagues who demonstrated hemispheric differences in summation priming (Beeman et al., 1994). They presented three word primes prior to presenting a target (e.g., scratch). The primes were either weakly related (cat, attack, paws) or unrelated to a target (church, grease, hurdle), with the target lateralized to either the right or the left hemisphere. They found greater summation priming in the RH than in the LH for the weakly related primes, suggesting that the RH is specialized for the detection of more distant semantic associates.

Overall, then, these studies suggest that both hemispheres activate closely related semantic information, but that they differ in

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the nature of that activation. The LH engages in close semantic coding, activating a restricted set of meanings and quickly settling on a dominant meaning. In contrast, the RH engages in more diffuse semantic coding, activating many different meanings and leaving them activated for a longer period of time. These differences are consistent with a variety of neurological data regarding differences between the right and left hemisphere (e.g., Jung-Beeman, 2005).

Although there is support for greater activation of distant semantic associates in the RH relative to the LH, the possibility that individuals with a more active RH might display coarse semantic coding to a greater extent than others has not been examined. There is one line of research, however, that suggests the existence of such a link. Specifically, there is research demonstrating a relationship between dispositional RH activation and proneness to paranormal beliefs, and it has been argued that this link is caused by the coarse semantic processing properties of the RH. For example, Pizzagalli and colleagues demonstrated stronger indirect priming in the RH for individuals with strong paranormal beliefs relative to nonbelievers (Pizzagalli, Lehmann, & Brugger, 2001) as well as greater RH activation (Beta waves assessed with resting EEG) for strong paranormal believers relative to nonbelievers (Pizzagalli et al., 2000). Relatedly, Taylor, Zäch, and Brugger (2002) reported significant correlations between magical ideation scores and a leftward shift in a line bisection task (and hence greater right hemisphere activation). It's possible, then, that the link between RH activation and paranormal beliefs is partly a function of the tendency of the RH to engage in coarse semantic processing.

### 3. Assessing arousal asymmetry

One method for assessing arousal asymmetry is to compare alpha-band EEG readings for the right and left hemispheres (e.g., Davidson, Ekman, Saron, Senulis, & Friesen, 1990). However, faster and less cumbersome techniques have been developed that involve behavioral tasks. One well-known measure in this regard is the line bisection task. With a line bisection task, participants are asked to locate the center of a line by marking the line to indicate what they perceive to be the middle point. The logic of the task is that participants tend to over-attend to a stimulus when it is processed by the more active hemisphere. Hence, when bisecting a line, those with a more active RH will tend to bisect to the left of the midpoint (because they over-attend to the left side); those with a more active LH bisect to the right of the midpoint. An alternative procedure is to ask participants to indicate which half of an evenly bisected line is larger (sometimes referred to as the Landmark task), a task that is entirely perceptual. Some evidence for the validity of the line bisection task comes from the observation that people with RH damage consistently under-perceive the left side of a line and hence err to the right of center when making line judgments (Cappa, Guariglia, Messa, Pizzamiglio, & Zoccolotti, 1991; Damasio & Damasio, 1980; Vallar & Perani, 1986). In contrast, intact controls tend to err to the left side reflecting an overall RH attention bias, referred to as pseudoneglect (Jewell & McCourt, 2000). Electro-physical/imaging research suggest that this is due to the role of the RH in early visual attention (Çiçek, Deouell, & Knight, 2009).

Importantly, however, there is considerable individual variability in line bisection performance (Manning, Halligan, & Marshall, 1990), and this variability is associated with differential hemispheric activation (Bjoertomt, Cowey, & Walsh, 2002; Oliveri et al., 2001). Most relevant for the current research Marsh et al. (2012) and Nash, McGregor, and Inzlicht (2010) have demonstrated that participants whose line bisection performance indicated greater RH activation displayed significantly lower alpha (an inverse indicator of cerebral activity) in the RH (but not LH) relative

to other participants. Moreover, research has demonstrated that individual differences associated with negative affect (He et al., 2010) and motivation (Nash et al. 2010) are significantly related to performance on the line bisection task. Regarding the former, He et al. report a significantly greater leftward bias in Generalized Anxiety participants relative to healthy participants. Regarding the latter, Nash et al., demonstrated an increased rightward line bisection bias for high (but not low) self-esteem participants when they were challenged (paralleling EEG measures of prefrontal asymmetry when challenged). Hence, individual differences and situational variables associated with hemispheric asymmetries can be detected with line bisection tasks.

## 4. The present research

Two experiments were conducted to examine individual differences in arousal asymmetry and its likely relation to differences in the activation of semantic associates. In both experiments arousal asymmetry was assessed with a computerized line perception task. The first experiment examined the relationship between arousal asymmetry and the ability to generate remote associates to three word stimuli. The second experiment examined differences in summation priming (Beeman et al., 1994) as a function of arousal asymmetry. If the RH is specialized for distant semantic associates as prior research suggests, then individuals with a more active RH should display greater activation of distant semantic associates relative to other individuals.

## 5. Experiment 1

In this study the relationship between arousal asymmetry and the ability to generate distant semantic associates was examined. To do this, participants completed a version of the line bisection task and attempted to solve remote associates problems (modeled after the Remote Associates Task, Mednick, 1962), a widely used measure of creative thinking and insight. For the latter task, participants were asked to produce a solution word (e.g., air) in response to three stimulus words (e.g., force, line, mail). It was expected that individuals with a more active RH would be better at this task than would others.

## 6. Method

### 6.1. Participants

Participants ( $N = 78$ ; 48 females) were undergraduate students enrolled in Introductory Psychology courses who participated for partial course credit. All participants spoke English as their first language. The data from four participants (two males and two females) were excluded because they failed to provide judgments on at least two of the ten critical lines. In preliminary analyses there were no main effects or interactions involving participant sex and this variable was excluded from subsequent analyses.

### 6.2. Materials

A computerized line perception task was developed for the current research. The line bisection task consisted of 20 bisected lines presented on the computer screen. Ten of the lines were bisected in the middle and constituted the critical trials. Filler trials included 5 lines that were bisected 1/16 in. to the right and 5 lines that were bisected 1/16 in. to the left. Lines not bisected in the center were included so as to identify participants who were responding randomly (no participants were excluded due to random responding) and to prevent participants from realizing that all stimuli were the

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