Consciousness and Cognition 38 (2015) 88–98

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Subliminal semantic priming in near absence of attention: A cursor motion study

Kunchen Xiao, Takashi Yamauchi *

Department of Psychology, Texas A&M University, Mail Stop: 4235, College Station, TX 77843-4235, USA

A R T I C L E I N F O

Article history:
Received 28 March 2015
Revised 7 August 2015
Accepted 30 September 2015

Keywords:
Consciousness
Attention
Congruency effect
Cursor motion

A B S T R A C T

The role of attention in subliminal semantic priming remains controversial: some researchers argue that attention is necessary for subliminal semantic priming, while others suggest that subliminal semantic processing is free from the influence of attention. The present study employs a cursor motion method to measure priming and evaluate the influence of attention. Specifically, by employing a semantic priming task developed by Naccache, Blandin, and Dehaene (2002), we investigate the extent to which top-down attention influences semantic priming. Results indicate that, consistent with the Naccache et al. (2002) results, attention facilitates priming. However, inconsistent with their theory, significant priming is still observed even in near absence of attention. We suggest that top-down attention helps but is not necessary for subliminal semantic processing.

1. Introduction

It has been debated for decades whether attention plays a fundamental role in subliminal semantic priming. A classic view is that subliminal processing is purely automatic requiring no attention (Schneider & Shiffrin, 1977). For example, the gist of pictures can be understood in near absence of attention (Li, VanRullen, Koch, & Perona, 2002); when a photograph was briefly flashed unexpectedly on a screen, subjects could accurately report a summary of the photograph, even though the photograph was presented at peripheral locations with a duration as short as 30 ms. It is also found that the gender and identity of faces can be rapidly processed when there is little top-down attention (Reddy, Wilken, & Koch, 2004). In addition, in a numerical judgment task, it is found that subliminal stimuli do have influences on cognitive control even in near absence of attention (Rahnev, Huang, & Lau, 2012).

However, other studies suggest that top-down attention is essential in subliminal semantic processing (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). For example, in an ERP study, top-down attention facilitates a N400 component during semantic processing of subliminal stimuli (Kiefer & Martens, 2010). Top-down attention is also shown to be *necessary* for subliminal processing of spatial information; without awareness, participants can correctly report locations of dots only when top-down attention is present (Hsieh, Colas, & Kanwisher, 2011). Furthermore, it is also suggested that processing the gist of natural-scenes involves top-down attention (Cohen, Alvarez, & Nakayama, 2011).

One of the most-cited studies arguing for the necessity of top-down attention is a number judgment task (Naccache, Blandin, & Dehaene, 2002), where participants' top-down attention was manipulated by occasionally presenting a visual cue (a green square) to signal an upcoming target. Participants judged whether a target digit (e.g. "9") was larger or smaller

* Corresponding author.
E-mail addresses: xiaokunchen@tamu.edu (K. Xiao), takashi-yamauchi@tamu.edu (T. Yamauchi).

http://dx.doi.org/10.1016/j.concog.2015.09.013
1053-8100/

than five, preceded by a masked priming digit (e.g. "6"). It was assumed that when both the prime and the target were bigger or smaller than five, response times would be shorter, known as congruency effects. Naccache et al. manipulated the effect of top-down attention by introducing two within-subjects conditions. In one condition (uncued condition), the pre-target duration in each trial was randomly set for either 1420 ms or 2130 ms, which disrupted participants' top-down attention to targets because participants could not predict when a target digit would appear. In the other condition (cued condition), to offset the disruptive impact on top-down attention, a green square cue was presented with a fixed duration prior to the target to facilitate participants' top-down attention. Results showed that congruency effects were present only in the cued condition. Based on these findings, Naccache et al. (p. 423; 2002) suggest that a temporal attention window is *necessary* for subliminal semantic priming: "It is plausible that stimuli presented under highly degraded conditions, as in our visual mask procedure, require a minimum amplification by attention, without which they are simply not processed at all." The assumed underlying mechanism is that: when participants focus their attention on an expected target, they open a temporal window of attention that lasts briefly (usually hundreds of milliseconds), which contributes to the processing of a prime presented temporally close to the target. Though the prime is invisible, paying attention to the invisible prime still amplifies subliminal processing, which results in significant congruency effects. In contrast, unseen primes that are not covered by the attention time window do not induce subliminal priming at a semantic level.

Naccache et al. (2002) claims that the theory of attention time window contradicts the spreading activation theory. According to the spreading activation theory, the subliminal information automatically activates the corresponding representations, and spread the activation through the neural network (Collins & Loftus, 1975; Kouider & Dehaene, 2007). Such spreading activation is said to be independent from conscious attention and attention modulation. However, the theory of temporal attention window suggests that the attention allocation does influence subliminal processing even when participants were unaware of primes.

Given that both the presence and absence of attention can result in priming, it is difficult to conclude that a top-down attention is the source of priming. Furthermore, the Naccache et al. (p. 423; 2002) was based on response time measures, which usually result in underestimated priming effects. A meta-analysis shows that masked semantic congruency effects, which have been measured almost exclusively by response times, are often weak and difficult to replicate (Van den Bussche, Van den Noortgate, & Reynvoet, 2009). The limited data solely based on response time measures may not be powerful enough to reveal subliminal semantic processing.

One reason for the inconsistency of evidence is the way that priming is assessed. Most behavioral data collected to evaluate masked semantic priming is based on the response time and accuracy, which provides only two data points in each trial. Response times are not informative enough concerning the dynamic cognitive processes that unfold within a short period of priming, which is yet fundamental for understanding elaborate subliminal processing. To probe these dynamic processes, a measurement recording fine-tuned data points corresponding to subliminal decision-making processes is needed.

Fortunately, a recently emerging technique allows us to assess behavioral data that is more sensitive to subliminal semantic priming: assessing trajectories of a computer cursor. (Dale, Kehoe, & Spivey, 2007; Gallivan & Chapman, 2014). In each trial, participants use a computer mouse to respond while running times and positions of the cursor are recorded every 10–20 ms to depict a cursor motion trajectory (Yamauchi, 2013; Yamauchi & Bowman, 2014; Yamauchi, Kohn, & Yu, 2007). The advantage of cursor motion measure is that it records real-time temporal-spatial information revealing participants' dynamic decision-making processes in addition to response time data (Freeman & Ambady, 2010, 2011). Traditional response time techniques record only the duration from the onset of a target until a response is made, yet the information concerning processes within this duration is missing. Such information, however, is important to understand subliminal processing. In contrast, the cursor motion technique integrating temporal-spatial information reveals real-time features of behavioral data and has better accuracy than measures recording only temporal data (McKinstry, Dale, & Spivey, 2008). By analyzing the temporal-spatial features of cursor motion trajectories, further insights can be gained to understand elaborate subliminal processing (Song & Nakayama, 2009; Spivey & Dale, 2006).

Early studies have demonstrated that hand motion in reaching tasks can reflect participants' unconscious judgment and decision-making processes (Aglioti, DeSouza, & Goodale, 1995; Milner & Goodale, 1995). Recently, a few studies have applied cursor motion measures to study subliminal semantic judgment. For example, perceptual and semantic priming can be distinguished by different cursor trajectory patterns (Finkbeiner & Friedman, 2011; Friedman & Finkbeiner, 2010). Congruency effects can be reliably measured by attractions toward unintended choices of cursor trajectories, and incongruent trials elicit larger attractions than congruent trials do (Xiao & Yamauchi, 2014).

Furthermore, quite a few studies have demonstrated the advantage of cursor/hand motion techniques over traditional reaction time techniques (Boulenger et al., 2006; Chapman et al., 2010; Faulkenberry, 2014; Faulkenberry & Rey, 2014; Santens, Goossens, & Verguts, 2011; Spivey, Grosjean, & Knoblich, 2005), particularly for the sensitivity to subliminal processing (Freeman, Johnson, Ambady, & Rule, 2010; Freeman, Pauker, Apfelbaum, & Ambady, 2010). A recent study comparing the cursor motion measure and response time measure reported that subliminal semantic priming was observed with both measures in the same number comparison task; however, the effect size of priming measured by cursor motion was far larger than that by response times (Xiao, Yamauchi, & Bowman, 2015).

On this basis, the absence of elaborate subliminal priming without assistance from top-down control reported in early studies may be attributed to the lack of sensitivity with response time measures. It is time to consider a new method to collect behavior data and study masked priming. Combining dynamic measures of cursor motion with masked priming procedures may serve as a powerful tool to characterize and uncover mechanisms of elaborate unconscious processing.