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Gaze-induced joint attention persists under high perceptual load and does not depend on awareness

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ABSTRACT

The automaticity of gaze-induced joint attention is well known in relatively easy cognitive tasks; but its role in harder tasks had never been examined. This encouraged us to study automaticity in hard tasks, tasks presenting the subjects with high perceptual loads. The Rapid Serial Visual Presentation (RSVP) paradigm was used to present participants with two streams of bilaterally displayed digit-flows while they fixated at the center of a synthetic representation of a human face. The face was presented both above (Experiments 1 and 2) and below (Experiment 3) the face's visual threshold (henceforth called "supraliminal" and "subliminal", respectively). Interocular suppression was used to make the face stimulus invisible (subliminal). In the critical trials of all three experiments, the gaze direction shown on the face was randomly diverted to either the left or to the right. This directed the participant's gaze either towards or away from the location of a target in the RSVP. The perceptual load was always relatively high. It was either set (Experiments 1 and 3) or manipulated (Experiment 2) during the experiment. In all three experiments, an appreciably higher and significant level of target detection was found when an uninformative gaze-cue was congruent with the location of the target. This result, which had only been reported with relatively easy tasks previously, is called the "gaze-cueing effect". Our novel findings include showing that: (i) the attentional effect of gaze persists under high perceptual loads, and (ii) awareness of the gaze stimuli is not required to obtain the gaze-cueing effect. They also serve to validate prior support for an important role of automaticity in gaze-induced joint attention.

1. Introduction

Gaze plays an important role in social interactions by providing cues that can assist a variety of social cognitive processes, such as recognizing emotional states and evaluating social situations (Adams et al., 2003; Adams & Kleck, 2005; Jones et al., 2006). A very basic, and probably the most often studied, effect of gaze is the social attentional effect. This effect includes findings such as: (i) *direct* gaze is highly effective in capturing visual attention (Conty et al., 2006; Senju, Hasegawa, & Tojo, 2005; Vuilleumier et al., 2005), and (ii) *averted* gaze evokes joint attention (Ricciardelli et al., 2009). Gaze-induced joint attention is said to occur when the individual observing an averted gaze aligns his/her attention with the direction of the averted gaze (Nuku & Bekkering, 2008). Directing attention to where gaze was directed encourages better performance at these locations. This result is called the "gaze-cueing effect" (e.g., Driver et al., 1999).

The gaze-cueing effect has been shown to have three characteristics. First, it is quick and reflexive. This effect is found with relatively short (105 and 300 ms) cue–target Stimulus Onset Asynchrony (SOA, Friesen & Kingstone, 1998), and with a temporal pattern similar to the pattern used to obtain what is called the "exogenous cueing effect", i.e., an attentional effect elicited by peripheral cues. Second, the gaze-cueing effect can also be observed even when the gaze-cue is neither informative nor related to the task (Frischen, Bayliss, & Tipper, 2007; Hietanen et al., 2008), and when a transient gaze-cue is presented subliminally (Sato, Okada, & Toichi, 2007). Third, the gaze-cueing effect has also been found to be free from top-down control, and it even appears when the gaze-cue is not predictive (Hill et al., 2010), or when participants are required to ignore or to respond in the direction opposite to the cued direction (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004).

All of these characteristics imply automaticity, which sets the gaze-cueing effect apart from other types of effects from attentional cues, such as those produced by arrows (Downing, Dodds, & Bray, 2004; Friesen, Ristic, & Kingstone, 2004). The support for the automaticity of gaze-induced joint attention is based mainly on what is called the "un-intentionality criterion" for automatic

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processing. This criterion states that a process is automatic only if it is neither facilitated by focusing attention on a certain stimulus nor inhibited when attention is focused elsewhere (Santangelo & Spence, 2008). This criterion was satisfied with all of the findings summarized above, i.e., the findings that task-irrelevant and uninformative gaze-cues produce the gaze-cueing effect (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; Frischen et al., 2007; Hietanen et al., 2008). But, there is another important criterion for automaticity which has never been tested for the gaze-cueing effect. It is called the "load-insensitivity criterion" (Schneider & Shiffrin, 1977; Yantis & Jonides, 1990). This criterion states that an automatic process should not be hindered by increasing the concurrent information load (Santangelo & Spence, 2008). This criterion has not been tested in studies of gaze-induced joint attention, and, to our knowledge, all previous studies have used relatively easy tasks that carry a comparatively low perceptual load. For example, in a typical spatial cueing paradigm, participants respond to the onset of the target without any distractions (e.g., Driver et al., 1999; Hietanen et al., 2008).

The purpose of our study was to find out whether there is a gaze-cueing effect when there is a high perceptual load. We thought that this should be done in order to establish the automaticity of gaze-cueing effect, because with a low perceptual load, participants might unwittingly utilize spare attentional resources to process task-irrelevant information, such as averted gazes. If they did this, one could question the automaticity of the gaze-cueing. In other words, the gaze-cueing effect is not actually caused by automaticity but by one's application of a specific processing strategy, such as processing as much information as possible, which might be done, if there are sufficient resources. So, examining whether gaze-processing persists under high perceptual loads can either rule out or confirm that automaticity plays an important role as has been claimed on the basis of the load-insensitivity criterion, but either outcome will enhance our understanding of the gaze-cueing effect. This investigation also has appreciable ecological validity, because in everyday life, we often have to divide our attention among multiple objects and process critical information with limited resources.

High perceptual loads were created by asking participants to detect a target in a bilateral Rapid Serial Visual Presentation (RSVP). An RSVP is a stimulus-stream display consisting of one or more targets and multiple distracters. Load-insensitivity was investigated within this paradigm. Experiment 1 asked whether the gaze-cueing effect would be found in a conventional high perceptual-load context created by the RSVPs, and if it is found, what is its time course? Either the lack of a gaze-cueing effect or any moderating effect of cue–target SOAs would suggest that automaticity was affected by the high perceptual load. Experiment 2 varied the amount of the perceptual load directly. This was done to provide more direct evidence on whether the gaze-cueing effect is insensitive to the load. It was important to do this because the automaticity claim about the gaze-cueing effect rests on the "load-insensitivity criterion" described earlier.

We also tested whether the gaze-cueing effect is contingent on the participants' awareness of the gaze-cue under high perceptual load. It is reasonable to speculate on the basis of some recent brain-imaging research, as well as from some psychophysical results, that gaze-cues despite being suppressed from awareness may be processed and evoke an attentional effect. This was a real possibility because many social cognitive processes are known to take place without awareness of their external social triggers. For example , the processing of selfness, familiarity, emotion, racial prejudice, and semantic information have all been observed with subliminally presented stimuli (Burton et al., 2005; Eastwood & Smilek, 2005; Habel et al., 2007; Jiang & He, 2006; Soto & Humphreys, 2009; Stone & Valentine, 2004, 2005; Suslow et al., 2006). Shifts of attention without awareness of their cues have also been reported (Danziger, Kingstone, & Rafal, 1998; Ivanoff & Klein, 2003; Kentridge, Heywood, & Weiskrantz, 1999a, 1999b; McCormick, 1997), but a subliminal gaze-cueing effect has only been reported once, namely, by Sato, Okada, and Toichi (2007). Their effect was smaller than the supraliminal effect found in a low-load condition with rapid exposures (17.5 ± 8.5 ms) of the gaze-cues and with Backward Masking (BM). Our Experiment 3 differed from Sato, Okada, and Toichi (2007) in the method we used to render gaze-cues invisible as well as in the perceptual load. We did not use BM. Instead, we used a prolonged subliminal presentation of the gaze-cues with continuous flash suppression (CFS), the technique used by Tsuchiya and Koch (2005). We did this because we thought that prolonging suppression would allow more subliminal processing than Backward Masking would allow. Furthermore, previous research had established that CFS obliterates the input into the ventral temporal regions, but leaves dorsal stream processes largely unaffected (Fang & He, 2005), but Backward Masking allows the suppressed information to reach both ventral and dorsal stream visual structures in the brain (Dehaene et al., 2001). Comparing results of our study with those of the Sato, Okada, and Toichi (2007) study also might shed some light on the role of the dorsal and ventral visual pathways in processing subliminal gaze because these two visual streams are in charge of distinct and different aspects of visual processing.

In summary, our present study was designed to increase our understanding of the automaticity of gaze-induced joint attention in two important directions, namely, load-(in) sensitivity and awareness-(in) dependency.

2. Experiment 1: Gaze-cueing effect under high perceptual load

Experiment 1 investigated whether the gaze-cueing effect is observed in a high perceptual-load setting, that is, whether a target's detection is facilitated when it is at the gaze-congruent location as oppose to when it is at the gaze-incongruent location. Our high perceptual load was implemented by having the participants' attention distributed among multiple ongoing events.

A within-subject factorial design was used, specifically, a 2 (Gaze Congruency: Congruent vs. Incongruent) × 2 (cue–target SOA: 0 ms vs. 318 ms) design. In the congruent condition, the direction of the face's gaze indicated the location of a simultaneous or following target, whereas in the incongruent condition the gaze-cue was directed to the location opposite to the target's. In the 0 ms- and 318 ms-SOA conditions, the gaze-cue was either given simultaneously with the target's appearance or preceded the target's appearance by 318 ms, respectively. This was done to find out how having a high perceptual load affected the onset-time of the gaze-cueing effect. Driver et al. (1999) and Hietanen et al. (2008) had reported that the gaze-cueing effect emerged quickly when the perceptual load was low but its onset time had never been studied under high-load conditions.

2.1. Participants

Twenty-three undergraduate students from Peking University participated in Experiment 1 as paid volunteers. All had normal or corrected-to-normal vision. Data from two participants failed to meet an accuracy criterion we employed and they were excluded from analysis: One participant's data were excluded because his accuracy of target detection was only 25%. All other participants had higher detection scores. They averaged >40%. The other participant's data were excluded because his proportion of incorrect target-location judgments was high relative to the other participants, >5% of all of his trials (not including misses)