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RESEARCH ARTICLE

The uniqueness of social attention revisited: working memory load interferes with endogenous but not social orienting

Dana A. Hayward · Jelena Ristic

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Abstract It is well known that perceived eye gaze direction influences attentional orienting. However, it still remains unclear whether social orienting involves exogenous or endogenous attentional control. To address this issue, we examined if social orienting and endogenous orienting were differentially modulated by working memory load, which is known to interfere with endogenous but not exogenous attention. To do so, we manipulated eye direction as either spatially counterpredictive in Experiment 1 or spatially predictive in Experiment 2 while participants performed a cueing task either in isolation or under working memory load. We found that when social attention and endogenous attention diverged spatially in Experiment 1, social orienting elicited by gaze direction remained intact while endogenous orienting elicited by the cue's predictive meaning was suppressed under working memory load, suggesting independence between social orienting and endogenous orienting. Indeed, a comparison between the sum of isolated social orienting and endogenous orienting magnitudes from Experiment 1 relative to their combined measure from Experiment 2 confirmed that social attention and endogenous attention operated in parallel. Together, our data show that social orienting is independent from endogenous orienting and further suggest that paying attention to social information might involve either exogenous or unique attentional mechanisms.

D. A. Hayward (✉) · J. Ristic (✉)
Department of Psychology, McGill University,
1205 Dr Penfield Ave, Montreal, QC H3A1B1, Canada
e-mail: dana.hayward@mail.mcgill.ca

J. Ristic
e-mail: jelena.ristic@mcgill.ca

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Introduction

A simple act of 'catching someone's glimpse' intuitively suggests that individuals tend to pay attention to where others are looking. During the past decade, a number of studies have investigated this phenomenon termed 'social orienting' (see Frischen et al. 2007 for a review), by employing a variant of a standard cueing task (Posner 1980). In this paradigm, social orienting is revealed by comparing participants' performance for targets that occur at locations that are gazed-at (i.e. cued) by a central face relative to targets that occur at not gazed-at (i.e. uncued) locations (Friesen and Kingstone 1998; Driver et al. 1999; Langton and Bruce 1999). Consistent with the idea that gaze direction influences attentional orienting, the data typically show facilitated response times (RTs) for gazed-at relative to not gazed-at targets (e.g. Friesen and Kingstone 1998; Driver et al. 1999; Langton and Bruce 1999; Tipples 2002; Frischen et al. 2007). In the last decade, social orienting has been investigated not only with healthy participants using a variety of methodologies (e.g. Schuller and Rossion 2001; Frischen et al. 2007; Greene et al. 2009), but has also been examined across a number of research domains, including the dynamics of primate social behaviour (e.g. Deaner and Platt 2003; Shepherd et al. 2006), complex human social behaviour (e.g. Tipples 2006; Deaner et al. 2007), and typical (e.g. Farroni et al. 2002) and atypical social and cognitive development (e.g. Senju et al. 2004; Ristic et al. 2005).

Despite considerable general interest, however, the phenomenon of social orienting has led to the development of a controversy in the field of attention (e.g. Klein and Shore 2000; Bonato et al. 2008; Klein 2009). Namely, the crux of the debate lies in the observation that attentional orienting elicited by a gaze cue that is irrelevant for the task (i.e. when gaze direction does not predict where the target will appear) cannot be explained by either of the two prevailing theoretical models of attentional control—*exogenous* attention, whereby attention is attracted reflexively by irrelevant sensory features of the stimulus (Posner 1980) or *endogenous* attention, whereby attention is committed volitionally to interesting events in the environment (Jonides 1981). Like exogenous attention, social orienting emerges quickly, by 100 ms post-cue, and in response to spatially nonpredictive and spatially counterpredictive gaze direction (Friesen and Kingstone 1998; Friesen et al. 2004; Tipples 2008). Like endogenous attention, on the other hand, social orienting emerges in response to a visually complex cue at fixation (Vecera and Rizzo 2004) and persists for up to a second post-cue without being replaced by inhibition at a previously attended location (inhibition of return, or IOR; e.g. McKee et al. 2007). Although the majority of past investigations support the conclusion that social orienting reflects the involvement of exogenous attention (Friesen and Kingstone 1998; Driver et al. 1999; Langton and Bruce 1999), the data indicating the role of endogenous factors should not be ignored. Moreover, given the evolutionary significance of gaze information and the distinct effects it exerts on attentional processes, it has also been proposed that social orienting might reflect the involvement of uniquely specialized social attentional mechanisms (Kingstone et al. 2000; Ristic et al. 2002). Thus, resolving the question about the nature of the attentional processes implicated during social orienting would not only help in interpreting the already existing data but would also aid in formulating future hypotheses about the role of attentional systems in the interpretation of social information. Here, we examined the extent to which social orienting was susceptible to interference from a concurrent cognitive task involving working memory load. In doing so, we were able to determine that social orienting does not involve endogenous attention.

One way to experimentally dissociate exogenous and endogenous attention is to examine the extent to which each process is modulated by the concurrent demand for cognitive resources. Jonides (1981) demonstrated that the demand for cognitive resources differentially affects exogenous and endogenous attention. Because exogenous orienting is effortless, as it is passively driven by the stimulus properties, it is unaffected by an increase in the tasks' cognitive demands, i.e., exogenous orienting is additive with demands for cognitive resources taxed by cognitive load. In contrast, because endogenous orienting is effortful, as it is actively driven by the participants' internal expectations about the target, its magnitude decreases with an increase in the tasks' cognitive demands, i.e., cognitive load interferes with endogenous orienting (e.g. Jonides 1981). Thus, if social orienting elicited by a spatially nonpredictive cue was under endogenous control, an increase in the concurrent demand for cognitive resources would lead to a corresponding decrease in the magnitude of social orienting. If, on the other hand, social orienting was not under endogenous control, an increase in the concurrent demand for cognitive resources would not affect its magnitude.

Law et al. (2010) recently provided evidence supporting the latter hypothesis. The authors presented participants with a typical gaze cueing task in which spatially nonpredictive gaze direction served as an attentional cue. The amount of cognitive demand was manipulated by adding a simultaneous working memory load. The authors found that the magnitude of social orienting remained unaffected by the addition of working memory load and concluded that social orienting depended on exogenous attention.

This result, however, offers only partial evidence in favour of the conclusion that social orienting relies on exogenous processes. This is because the role of endogenous factors was not ruled out. That is, Law et al. (2010) provided evidence that social orienting was unaffected by working memory load, but did not present evidence that the working memory load successfully interfered with endogenous attention. This is a critical step in dissociating the contributions of exogenous and endogenous attention when using a cognitive load manipulation, as it is possible that, due to the relatively undemanding primary cueing task, participants may have had enough available cognitive resources to complete both the cueing task and the working memory task without interference.

To address this issue, in Experiment 1, we dissociated the effects of social attention and endogenous attention spatially by manipulating the gaze cue as counterpredictive of the target's location (Friesen et al. 2004; Tipples 2008). When gaze cues are made spatially counterpredictive, participants' social attention is committed to the gazed-at location while their endogenous attention is committed to the opposite location which is likely to receive the target (Friesen et al. 2004; Tipples 2008). Relative to Law et al., this manipulation increases the attentional demands of the primary cueing task as participants are now asked to both interpret the spatial meaning of the cue and to shift their attention endogenously away from the cue. In Experiment 2, we further examined the relationship between social orienting and endogenous orienting by comparing the magnitudes of social orienting and endogenous orienting when they converged onto the same spatial location relative to when their effects diverged in space in Experiment 1.

Experiment 1

One possibility for why Law et al. observed an additive relationship between social orienting and working memory load is that the primary cueing task was relatively undemanding. That is, because the gaze cue was spatially nonpredictive and endogenous attention was not explicitly recruited, participants may have had enough cognitive resources available to orient their attention endogenously in response to gaze direction and to perform the working memory task without interference. One way to address this issue is to present participants with a more demanding counterpredictive cueing task, in which the effects of working memory load can be assessed simultaneously on both social orienting and endogenous orienting. If social orienting was independent from endogenous control, we expected to observe no modulations of social orienting but suppressed endogenous orienting under working memory load due to the interaction between endogenous attention and the cognitive processes required to perform the working memory task. That is, as one's cognitive resources become taxed by the working memory load, participants' ability to orient attention endogenously, but not socially, should become impaired.

Methods

Participants

Twenty-eight ($N = 28$) participants were randomly assigned to each of the two working memory load groups (no load; load; total $n = 56$; mean age: 20.1, range 18–30, 44 females). All experimental procedures have been approved by the McGill University Research Ethics Board and adhere to the principles of the Helsinki Declaration. Written informed consent was obtained from all participants.

Apparatus and stimuli

Figure 1 shows the stimuli and an example sequence of events. Stimuli were rendered in grey scale and were shown against a white background on a 16-in CRT monitor. The photograph portraying a female face (5.4° × 4.4°) displaying left, right, up or down gaze deviation was presented at

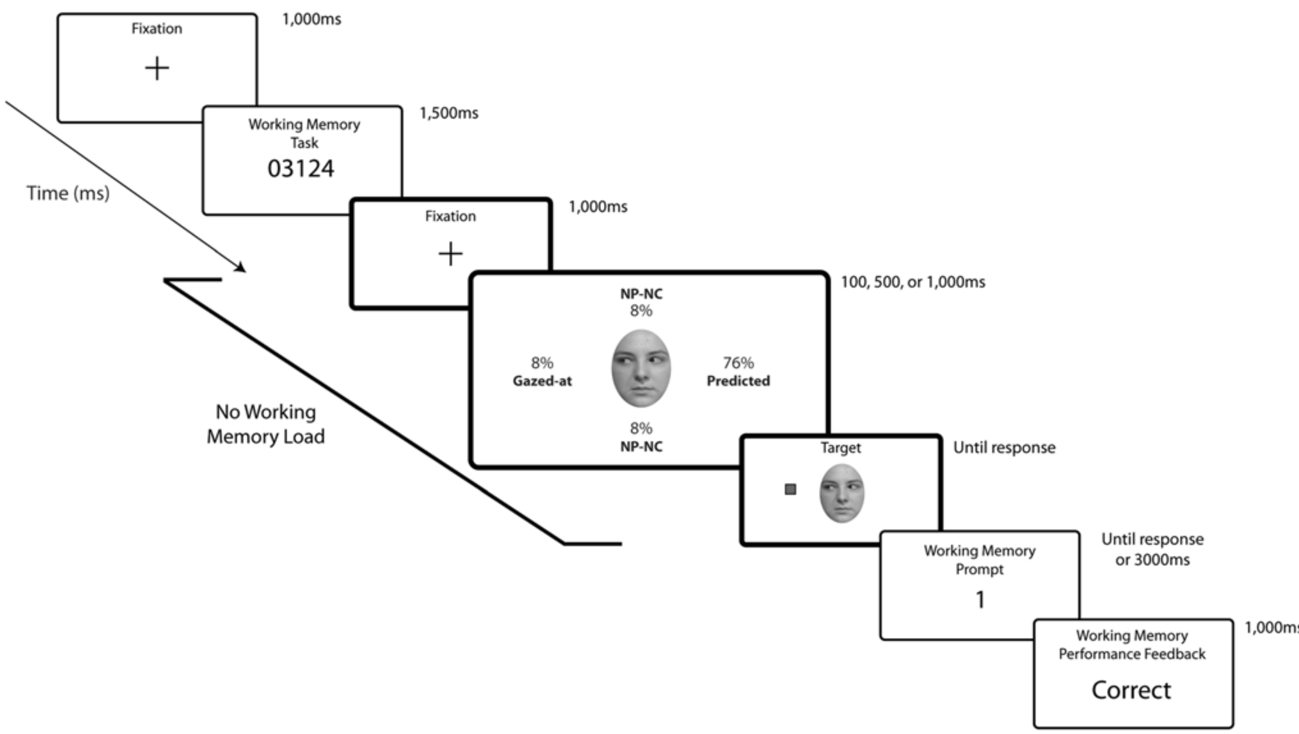

Fig. 1 Example task sequence. In the no-load condition, the cueing task was presented in isolation. Each trial began with 1,000-ms fixation, then a photograph of a face displaying left, right, up or down gaze appeared. Next, the target was shown after 100, 500 or 1,000 ms, with both the cue and the target remaining visible until response. In the load condition, the cueing task was embedded within a working memory task. Again, each trial began with 1,000-ms fixation, followed by the working memory load task shown for 1,500 ms, followed by the cueing task sequence. After the response was made in the cueing task, a memory prompt was shown for 3,000 ms or until response. The working memory performance feedback ('correct', 'incorrect' or 'no response') was displayed at the end of each trial for 1,000 ms. The gaze cue was counterpredictive of the target's location such that the target appeared at the location opposite to gaze direction in 76 % of trials (i.e. predicted location). The target appeared equally often (i.e. 8 %) at the other three possible locations, i.e., the gazed-at and the not-predicted–not-cued (i.e. NP-NC) locations. Note that stimuli are not drawn to scale

fixation. The target was a grey square subtending 1°, shown at an eccentricity of 6° away from central fixation along vertical and horizontal meridians. The working memory task included a presentation of a string of five digits rendered in Arial font (1.5° × 1° each).

Design and procedure

Working memory load was a between-subjects variable, while cue validity (gazed-at, predicted, and not-predicted and not-cued targets), which allowed us to measure the effects of the gaze cue on attention, and cue-target interval (100, 500 and 1,000 ms), which allowed us to measure the time course of attentional effects, were within-subjects variables.

On any given cueing trial, the face cue displayed either a left, right, up or down gaze deviation and the target could appear to the left, right, above or below of fixation. Gaze direction was counterpredictive of the target's location, such that the target appeared on the opposite side of the gazed-at location in 76 % of trials. Social orienting occurred on trials in which the target appeared at the gazed-at location. Endogenous orienting occurred on trials in which the target appeared at the opposing predicted location (Friesen et al. 2004; Tipples 2008). The effects of both social attention and endogenous attention were assessed relative to trials in which the target occurred at one of the two remaining not-predicted and not-cued locations (i.e. NP-NC; cf. Friesen et al. 2004), thus providing a way to assess the contribution of both social orienting and endogenous orienting relative to a common comparison condition. Although social attention and endogenous attention diverge spatially when the cue is counterpredictive, they co-occur temporally exerting simultaneous attentional effects at both early (e.g. 100 ms; Tipples 2008) and late cue-target intervals (e.g. 600 ms, Friesen et al. 2004; 1,200 ms, Tipples 2008). This design thus engaged both social attention and endogenous attention by the same cue within a single experiment while requiring increased deployment of attentional resources, as participants were asked to orient their endogenous attention away from the cue (Friesen et al. 2004; Tipples 2008).

As illustrated in Fig. 1, in the no-load condition, participants performed the cueing task in isolation (e.g. Bayliss and Tipper 2006; Galfano et al. 2012). In the load condition, in addition to the cueing task, participants also performed a working memory task (e.g. Lavie and de Fockert 2005), where they were asked to remember a string of five digits before starting each cueing trial and to report on them at the end of each cueing trial.

All trials began with a 1,000-ms presentation of a fixation display. In the no-load condition, the fixation display was followed by the presentation of the gaze cue. After a variable cue-target interval (100, 500 or 1,000 ms), the target demanding a simple detection response (i.e. spacebar key press) was presented.[1] In keeping with the previous studies conducted on this topic, the cue and the target remained on the screen until a response was made (Friesen and Kingstone 1998; Driver et al. 1999; Langton and Bruce 1999). In the load condition, each cueing trial was flanked by the working memory task. Here, after the fixation display, the participants were shown a to-be-remembered string of digits for 1,500 ms, which always began with a 0 and was followed by a random combination of the numbers 1, 2, 3 and 4 (cf. Lavie and de Fockert 2005; Law et al. 2010). After completing the cueing task, which immediately followed the memory task, a memory prompt, in the form of a single digit, appeared on the screen and participants were asked to input the next number in the to-be-remembered sequence from the start of the trial by pressing either the 'c', 'v', 'b' or 'n' key on the keyboard (corresponding to digits 1, 2, 3 and 4). Finally, working memory performance feedback ('correct', 'incorrect' or 'no response') was displayed for 1,000 ms at the end of each trial.

Participants viewed the stimuli from an approximate distance of 57 cm and were asked to fixate the centre of the screen and to respond as quickly and as accurately as possible. Each participant was informed about the counterpredictive contingency and completed a total of 468 trials divided over 3 testing blocks. Response time (RT) was measured from target onset and was based on keyboard responses. Cue direction, target location and cue-target intervals were presented equally in a pseudorandom order within each participant.

Results

All trials with response anticipations (RTs < 100 ms), missed responses (RTs > 1,000 ms) or those containing a response error (i.e. incorrect key press on the cueing task or an erroneous response on the working memory task) were excluded from analyses. Errors on the cueing task were infrequent, with overall accuracy exceeding 99 % and false alarms falling below 3 % in each group. Performance accuracy on the working memory task was 93 %.

As shown in Fig. 2, and replicating past data (Friesen et al. 2004; Tipples 2008), both social orienting elicited towards the gazed-at location and endogenous orienting elicited towards the predicted location were observed. The key question was whether working memory load differentially modulated social orienting and endogenous orienting. To address this question, we subjected mean correct RTs to two separate mixed effects ANOVAs run as a function of

[1] Instead of a target localization task as employed by Law et al. (2010), here, we used a target detection task in order to avoid well-documented issues that arise from the interactions between endogenous attention and response preparation (e.g., Spence and Driver 1997; Klein 2004).

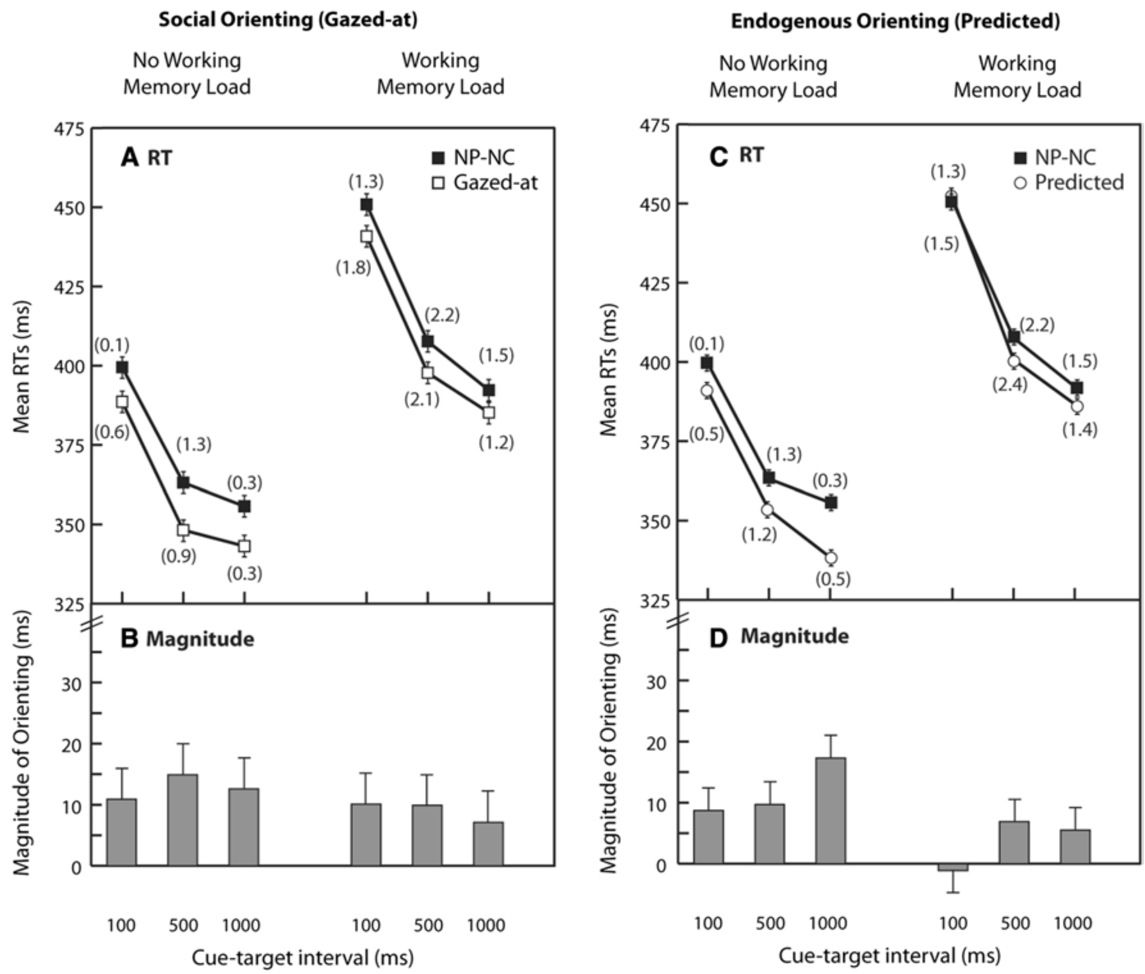

Fig. 2 Experiment 1 Results. **a**, **c** Mean correct response times (RTs) for social orienting and endogenous orienting, respectively, as a function of working memory load, cue validity and cue-target interval. Per cent errors on target-present trials are denoted in *brackets*. **b**, **d** Depict the associated magnitudes of social orienting and endogenous orienting. *Error bars* depict the standard error of the difference between the means

load, cue-target interval, and cue validity (gazed-at vs. NP-NC for social orienting; predicted vs. NP-NC for endogenous orienting).[2,3]

Effects of working memory load on social orienting

Conceptually replicating Law et al. (2010) and as shown in Fig. 2a, social orienting did not vary as a function of load (all effects involving load Fs < 1). As expected, however, we observed faster responses for gazed-at relative to NP-NC trials (360 vs. 373 ms), confirming that social orienting was elicited towards the gazed-at location [$F(1,54) = 22.8$, $p < .001$], with the orienting effect remaining stable across all cue-target intervals (cue validity × cue-target interval, $F < 1$). Participants responded overall slower under load [$F(1,54) = 12.7$, $p < .001$, 366 vs. 412 ms], indicating the effectiveness of the working memory load manipulation, and utilized the cue as a temporal warning signal [$F(2,108) = 62$, $p < .001$; all other effects Fs < 1].

Effects of working memory load on endogenous orienting

In contrast, endogenous orienting decreased reliably under working memory load, as shown in Fig. 2c (load × cue validity, $F(1,54) = 4$, $p = .05$). As suggested by this interaction, facilitated responses for predicted relative to

[2] Like in previous studies, an omnibus ANOVA was not used because it does not directly test the research hypotheses relating to modulations of social orienting versus endogenous orienting as a function of load, and as such does not reveal changes in the critical effects between each social orienting and endogenous orienting relative to the NP-NC condition (see Tipples 2008).

[3] Both social and endogenous orienting did not vary as a function of cue-target axis (horizontal vs. vertical). An ANOVA with load (no load; load; between-subjects variable), cue-target axis (vertical; horizontal), cue validity (gazed-at; predicted; NP-NC) and cue-target interval (100, 500 1,000 ms; within-subjects variables) indicated no main effects or interactions involving cue-target axis (all Fs < 2, all ps > .15).

NP-NC targets emerged under the no-load [$F(1,27) = 25$, $p < .001$, 361 vs. 373 ms] but not under the load condition ($F < 2$, $p > .2$, 413 vs. 417 ms). Participants once again responded slower overall under load [$F(1,54) = 13.4$, $p < .001$, 367 vs. 415 ms], the orienting effect remained stable across cue-target intervals (cue validity × cue-target interval, $F = 1$), and the temporal warning signal was reliable [$F(2,108) = 92.3$, $p < .001$; all other effects Fs < 2, ps $> .2$).

Thus, as expected (e.g. Tipples 2008) both RT analyses indicated that social orienting and endogenous orienting diverged spatially but overlapped temporally. This was further confirmed by an additional repeated measures ANOVA, which contrasted gazed-at and predicted RTs directly and returned no reliable differences (all Fs < 1.5, ps $> .2$).

Magnitudes of social orienting and endogenous orienting

To confirm these results, we also analysed the magnitudes of social (i.e. NP-NC–gazed-at RTs) and endogenous orienting (NP-NC–Endogenous RTs) using two mixed effects ANOVAs run as a function of load and cue-target interval. As shown in Figs. 2b, D, the magnitude of social orienting did not vary with load (12.8 vs. 9 ms, $F < 1$) or cue-target interval ($F < 1$) while the magnitude of endogenous orienting decreased under load [$F(1,54) = 4$, $p = .05$; 12 vs. 4 ms] steadily across cue-target time ($F = 1$; load × cue-target interval, $F < 1$).

Thus, Experiment 1 revealed that when participants committed their endogenous attention away from the gaze cue, thereby spatially dissociating social orienting and endogenous orienting, social orienting elicited towards the gazed-at location was unaffected by the addition of working memory load while endogenous orienting elicited towards the predicted location was suppressed under working memory load. Importantly and replicating past studies that have used the same task settings (Tipples 2008; Experiment 2), social orienting and endogenous orienting co-occurred at both short and long cue-target intervals. Further, relative to Law et al.'s Experiment 1, the magnitude of orienting elicited towards the gazed-at location by a counterpredictive gaze cue in the present experiment displayed identical overall magnitudes under load as the magnitude of social orienting elicited by a spatially nonpredictive gaze cue (9 vs. 9 ms). This suggests that the attentional effects elicited by spatially nonpredictive and spatially counterpredictive gaze direction reflect social orienting similarly.

Extending past reports, however, our result showing differential modulation of social orienting and endogenous orienting by working memory load strongly suggests that social orienting and endogenous orienting constitute independent processes. One way to test this idea is to compare these isolated and spatially divergent social and endogenous effects with a condition in which both types of attention are committed to the same spatial location, i.e., when the gaze cue is spatially predictive. If social attention and endogenous attention are independent, the sum of the isolated social and endogenous magnitudes should approximate the magnitude of orienting observed when both types of orienting converge onto the same spatial location. We tested this hypothesis in Experiment 2.

Experiment 2

While our data from Experiment 1 suggested that social attention and endogenous attention were independent, there are reasons to believe that the two processes might interact when both are committed towards the same spatial location. This reasoning follows from previous studies, which have employed spatially predictive nonsocial cues like arrows and found that such manipulations resulted in a superadditive combination between exogenous attention elicited by the cue's direction and endogenous attention elicited by the cue's predictiveness (Ristic and Kingstone 2006, 2009; Olk et al. 2008). Therefore, one might hypothesize that a similar interaction might also be observed when social gaze cues are employed in a similar manner, as many previous studies have reported that social eye gaze and nonsocial arrow cues produce indistinguishable attentional effects when they are manipulated as spatially nonpredictive (Stevens et al. 2008; Tipper et al. 2008; Brignani et al. 2009; Kuhn and Kingstone 2009). Thus, in Experiment 2, we measured the combined effect of social orienting and endogenous orienting when both processes converged onto the same area of space by using a spatially predictive eye gaze cue. If social orienting is independent from endogenous orienting, the additive sum of the isolated social and endogenous effects from Experiment 1 from the no-load condition should approximate the magnitude of attentional orienting observed in the present Experiment 2 when both processes converged onto the same spatial location.

Methods

Participants, apparatus, stimuli, design and procedure

Nineteen additional participants ($N = 19$) were recruited (mean age: 19.7, range 18–22, 18 females). The task parameters were kept the same as in Experiment 1 except for the following: (1) Only the no-load condition was run in order to unambiguously assess the combined effect of social orienting and endogenous orienting; (2) The gaze cue portrayed a male face (5.7° × 4.8°); (3) There were two possible cue directions and target locations—left and right; and (4) The direction of gaze correctly predicted the target location in 80 % of trials. Participants completed 240 trials divided over 4 testing blocks with approximately 7 % of trials containing no target.

Results

Once again, response errors were rare with an overall accuracy of 99 % and false alarm rate of 2 %. If social orienting and endogenous orienting were independent, an additive sum of the isolated components of social orienting and endogenous orienting as indexed by Experiment 1 no-load condition should closely approximate the magnitude of orienting obtained when social orienting and endogenous orienting converged onto the same spatial location in Experiment 2. To facilitate this comparison, we first verified that the spatially predictive gaze elicited the expected attentional effects. As shown in Fig. 3a, a repeated measures ANOVA conducted on mean correct RTs with cue validity and cue-target interval as factors indicated that overall participants responded faster to targets occurring at cued relative to uncued target locations [$F(1,18) = 34.3$, $p < .001$], with the attention effect growing with cue-target time [cue validity × cue-target interval, $F(2,36) = 3.8$, $p < .05$]. As before, a typical foreperiod effect (e.g. Bertelson 1967), i.e., overall facilitation of RTs with lengthening of cue-target intervals, was reliable [$F(2,36) = 50.1$, $p < .001$]. An identical result indicating an increase in orienting magnitude with cue-target time emerged when the magnitudes of orienting (uncued–cued RTs) were analysed across the cue-target times [$F(2,36) = 3.8$, $p < .05$], as shown in Fig. 3b. Thus, replicating previous data (e.g. Bayliss and Tipper 2006), spatially predictive gaze cue elicited reliable attentional effects.

To assess the relationship between social orienting and endogenous orienting, next we compared the sum of the isolated social (NP-NC–gazed-at RTs) and endogenous (NP-NC–predicted RTs) magnitudes of orienting from the no-load condition in Experiment 1 with the magnitude of orienting obtained in the present Experiment 2 (uncued–cued RTs) across the cue-target intervals. As illustrated in Fig. 4, a two-way mixed effects ANOVA with Experiment (Experiment 1; Experiment 2) and cue-target interval (100, 500 and 1,000 ms) indicated that the additive sum of isolated social orienting and endogenous orienting effects from Experiment 1 did not reliably differ from the magnitude of combined social orienting and endogenous orienting effects elicited by a spatially predictive gaze cue in Experiment 2 (24.7 vs. 24.8 ms, $F < 1$) across all cue-target intervals (Experiment × cue-target interval, $F < 1$). Thus, social orienting and endogenous orienting proceeded in parallel regardless of whether their attentional effects diverged spatially or converged onto a common spatial location. Put simply, the data from our two experiments strongly suggest that social orienting and endogenous orienting are independent and do not interact.

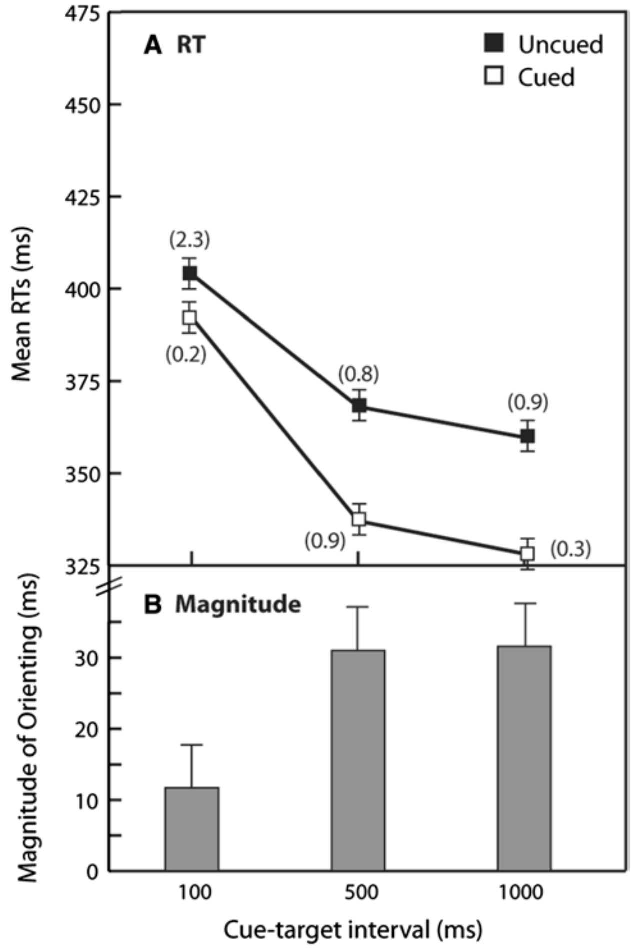

Fig. 3 Experiment 2 Results. **a** Mean correct response times (RTs) as a function of cue validity, and cue-target interval. Per cent errors on target-present trials are denoted in *brackets*. **b** Depicts the associated magnitudes of orienting. *Error bars* depict the standard error of the difference between the means

General discussion

Many studies conducted in the past decade have demonstrated that gaze direction elicits attentional orienting (Frischen et al. 2007). However, the field of attention continues to struggle with a theoretical explanation for the observed effects, as orienting elicited by task irrelevant gaze direction displays behavioural characteristics associated with both classic exogenous and endogenous attention. Here, we tested whether social orienting and endogenous orienting were differentially susceptible to interference from cognitive, i.e., working memory load. Based on the past literature (e.g. Jonides 1981; Law et al. 2010), we

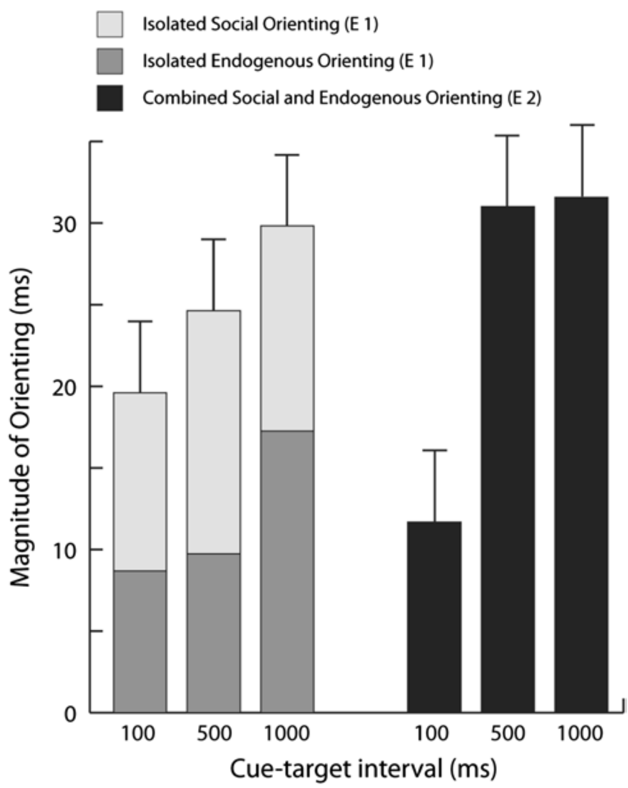

Fig. 4 Comparison of orienting effects across Experiments 1 and 2. It shows the additive combination of the magnitudes of isolated social orienting (NP-NC–gazed-at RTs) and endogenous (NP-NC–predicted RTs) orienting from the no-load condition of Experiment 1 and the magnitude of combined social orienting and endogenous orienting (uncued–cued RTs) from Experiment 2 as a function of cue-target interval. *Error bars* depict the standard error of the difference between the means

reasoned that if social orienting was mediated by endogenous mechanisms, which share resources with effortful cognitive processes like working memory, the magnitude of social orienting should decrease under working memory load. The data from both of our experiments did not support this hypothesis.

Extending past reports (Law et al. 2010), in Experiment 1 when we spatially separated the effects of social attention and endogenous attention, we found that social orienting elicited by the direction of gaze remained unaffected by working memory load, while endogenous orienting elicited by the gaze cue's predictive information was suppressed. This strongly suggested that social orienting and endogenous orienting were independent. The data from Experiment 2 supported this conclusion as the combined magnitude of social attention and endogenous attention elicited by a spatially convergent predictive gaze cue did not differ from the additive sum of isolated spatially divergent social and endogenous effects. Taken together, these data suggest three conclusions about social orienting.

One, social orienting appears to be resilient to demands for cognitive processing resources. This follows both from past studies which have found that social orienting elicited by spatially nonpredictive cues was unaffected by working memory load (Law et al. 2010) as well as from the present data in which we have found similar resilience of social orienting to working memory load within a more demanding counterpredictive cueing task. These data strongly suggest that social orienting is a relatively effortless process that does not depend on endogenous control.

Two, furthermore, our data suggest that social orienting is independent from endogenous attention. When gaze direction was spatially counterpredictive in Experiment 1, both social attention and endogenous attention were concurrently engaged towards different spatial locations. When gaze direction was spatially predictive in Experiment 2, both social attention and endogenous attention were concurrently engaged towards the same spatial location. The comparison between those two experiments indicated that committing both types of attention towards the same location closely approximated the additive sum of isolated social and endogenous components when they were committed towards two different spatial locations at both short and long cue-target intervals. Thus, in contrast to nonsocial arrow cues, engaging social orienting and endogenous orienting using a spatially predictive cue resulted in an additive rather than a superadditive combination of the two processes. This finding once again offers firm support for the notion that social attention and endogenous attention are independent.

Finally, although the present data and the majority of past data (Friesen and Kingstone 1998; Langton and Bruce 1999; Friesen et al. 2004) are consistent with the notion that social orienting involves exogenous rather than endogenous control, the final alternative that social orienting might be unique still remains tenable for three key reasons. One, due to the evolutionary significance of eye gaze, its fundamental role in human social communication (Friesen and Kingstone 1998; Kobayashi and Hashiya 2011), and existing functional specializations in the human brain (Kanwisher et al. 1997; Nummenmaa and Calder 2009), it is reasonable to hypothesize that attentional processes may also be specialized for responding to social information in the environment. Two, the data from the current study and those from previous investigations without exception show that social orienting does not conform to the standard performance template associated with exogenous attention. That is, social orienting is not marked by the typical biphasic performance pattern, consisting of early RT facilitation and later emerging IOR (Klein 2009) which is often taken as an experimental marker of exogenous orienting (Posner et al. 1985; Rafal et al. 1989). Three, social orienting has previously been found to occur in parallel with exogenous attention elicited by peripheral luminance transients (Friesen and Kingstone 2003) while here we demonstrated that it also occurred in parallel with endogenous attention. Additionally, our results also revealed that attentional systems combined differently when they were engaged by social (i.e. eye gaze) relative to nonsocial (i.e. arrow) information, suggesting once again that social information engages attention differently from nonsocial information (e.g. Ristic and Kingstone 2012). One way to assess the final alternative that social orienting involves unique attentional processes would be to apply experimental methods known to interfere with exogenous attention. If social orienting is exogenous, it should be disrupted by such a manipulation. Alternatively, the implication is that social orienting is neither exogenous nor endogenous, a result that would suggest important extensions to the prevailing theoretical conceptualization of attentional processes and their role in social communication.

In summary, in two experiments, we examined the effects of cognitive processing demands, i.e., concurrent working memory load on social orienting and endogenous orienting. Our data indicated that social but not endogenous orienting was resilient to working memory load. While this finding is consistent with the notion that social orienting is independent from endogenous control and instead involves exogenous attention, it does not rule out the possibility that social orienting might engage unique attentional processes. Future studies are needed to address this final outstanding question.

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