

REFLEXIVE ATTENTION ORIENTING
TRIGGERED BY EYE GAZE AND
ARROWS. AN EVENT-RELATED
POTENTIAL STUDY.

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The present study explored attention orienting by biologically relevant eye gaze cues and symbolic arrow cues. Participants were 19 university students aged 19-26 years (mean 22 years). Behavioural and EEG data (event-related potentials) were measured and analysed. The purpose of the study was to explore whether eye gaze and arrow cues result in similar reflexive attention orienting and whether the attention orienting effects observed in previous studies are based on similar underlying neural mechanisms. In previous behavioural studies, shorter reaction times have been observed in congruent trials (trials, where the location of the target stimulus is validly cued), than in incongruent trials (trials, where the location of the target is cued invalidly) or neutral trials (trials, where the location of a target is not cued). In event-related potential studies, eye gaze cuing has resulted in shorter latencies and enhanced amplitudes of the visual components P1 and N1, whereas symbolic cues have normally resulted only in amplitude enhancements. In the present study, both eye gaze and arrow cues resulted in shorter reaction times in congruent than in incongruent or neutral trials. There were no significant differences in reaction times in neutral and incongruent trials. The results indicate that the shorter reaction times in congruent trials for both types of cues reflect facilitation in the processing of congruent stimuli (a benefit effect) without there being any cost in the processing of unattended stimuli. Event-related potential recordings showed that both eye gaze and arrow cues resulted in speeded and enhanced P1 and N1 components of visual attention. The results were not fully conclusive but rather electrode-dependent. Some distinctive effects of cue type were observed in amplitudes of the components. Both components peaked faster in gaze than in arrow trials. The different time course of visual components between the two cue types may be an indication of separate underlying neural mechanisms for reflexive attention orienting by the two cue types. However, despite the different time course for the two cue types, there were little distinctive effects, which may indicate that eye gaze and arrow cues may share at least some similar attentional processing mechanisms. Further studies are proposed to address the issue by using a similar spatial cuing paradigm.

Key Words: eye gaze, arrows, attention orienting, event-related potentials

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1.Introduction

1.1. Reflexive attention orienting is triggered by gaze direction

Information about another person's gaze direction is important in social interaction. Eye gaze is a socially relevant stimulus; it has many functions: for example, it expresses intimacy and regulates turn-taking in conversations (Kleinke, 1986). Gaze direction gives us information about the direction of another person's attention. It has been shown that human infants as young as 3 months old look in the same direction as the eyes of an adult face (Hood, Willen, & Driver, 1998). It has been suggested that gaze direction provides us with information that is important to us evolutionarily by promoting our survival. It is thus also a biologically relevant stimulus. The other person, could, for example, be looking at a potential danger in the environment and therefore it is vital for us to be able to orient our attention in the same direction that the other person is looking. Moreover, it has been shown that another person's gaze direction automatically shifts our attention to the direction the other person is looking (Driver et al., 1999; Friesen & Kingstone, 1998, 2004; Hietanen, 1999; Langton & Bruce, 1999; Ristic, Friesen, & Kingstone, 2002).

This automatic attention orienting effect has been studied by using a modification of Posner's (1980) classic spatial cuing paradigm. In a typical study, a gazing face appears at central fixation, and then a target appears either at a gazed-at location (a congruent trial) or at another location (an incongruent trial). In so-called neutral trials, the preceding cue is a face gazing forward. The subject's task is to detect the target stimulus (for example, an asterisk appearing at a peripheral location on a computer screen) as fast as possible. The fact that subjects detect targets appearing at congruent locations faster than targets appearing in incongruent locations or in neutral locations has been considered as evidence for that gaze cue triggers automatic attention orienting. The automatic attention orienting effect has been called reflexive, as it has the properties of exogenous¹ cueing mechanisms: the reflexive attention shift can be

¹ A distinction has been made between attention orienting generated via exogenous (sensory) cues and endogenous cues (Jonides, 1981; Müller & Rabbit, 1989). Exogenous attention orienting is automatic and reflexive, whereas endogenous attention orienting is voluntary and takes a longer time to come about. Exogenous orienting was previously thought to occur only with non-predictive peripheral cues (such as a light flash presented at the periphery of visual field), in contrast to endogenous orienting, which was thought to occur with predictive centrally presented cues (Posner, 1980).

observed at very short stimulus-onset-asynchronies (SOAs) between the appearance of the face cues and targets, less than 100 milliseconds (Hietanen & Leppänen, 2003), and it disappears by 1000 ms (Friesen & Kingstone, 1998). The attention shift can be observed when subjects are told that the gaze direction is non-predictive (i.e. congruent and incongruent trials are presented with an equal probability) of the location of upcoming target stimulus (e.g. Driver et al. 1999; Friesen & Kingstone, 1998), and even when the subjects are told that the target is more likely to appear in the opposite direction to where the face is gazing than in the same direction (Driver et al. 1999; Friesen & Kingstone, 2004, experiment 1).

1.2. Arrows also trigger reflexive attention orienting

Friesen and Kingstone (1998) proposed that the reflexive shift of attention by gaze cues might represent an attention process that is unique to biologically relevant stimuli and that it may be subserved by brain regions that are specific to the processing of faces and eyes. However, reflexive shift of attention has also been shown to occur with arrows (symbolic cues) (Ristic et al., 2002; Tipples, 2002). Arrows are used as direction symbols in many situations where humans have to shift their attention rapidly, for example when reacting to road signs (Tipples, 2002). Orienting by arrows has previously been considered to be a form of endogenous orienting because the information must be decoded first and only after that can attention be voluntarily allocated to the pointed location (Mangun, 1995). Ristic et al. (2002) and Tipples (2002) proved that this is not the case: centrally presented arrows produced behaviourally similar reflexive attention orienting effects as did the gaze cues in previous studies. However, more recently Friesen and Kingstone (2004, experiments 1 & 2) proposed that attention orienting triggered by gaze direction is more reflexive in nature than attention orienting triggered by arrows. In the experiment, both gaze and arrow cues were counter-predictive (i.e. target was more likely to appear in the opposite direction to where the cue indicated than in the cued location). At the SOA of 105 ms, reflexive attention orienting effects were observed only when the preceding cue was eye gaze. Counter-predictive arrows produced only volitional attention orienting. Attention did not shift reflexively to the cued location, but reaction times were always shorter when target appeared at the predicted location (opposite to where the cue indicated it to appear). This led Friesen and Kingstone to

suggest that attention orienting triggered by gaze direction is based on special neural mechanisms and is unique in nature.

1.3. Processing of faces in the brain

Faces convey a great amount of information that is important to us from both a social and a biological perspective. We probably spend a longer time looking at faces than any other stimuli. Therefore, it has been suggested, that the analysis of faces may be unlike that of any other stimuli: there seem to be cognitive and neural mechanisms specialized in the analysis of faces and facial properties. Imaging studies have shown that specific areas in the brain are active when we are looking at faces. These areas have been found in the temporal lobe: especially in the fusiform gyrus (Halgren, Raji, Marinkovic, Jousmäki, & Hari, 2000; McCarthy, Puce, Gore, & Allison, 1997) and superior temporal sulcus (Allison, Puce, & McCarthy, 2000). Haxby, Hoffman, and Gobbini (2000) have proposed that there is a special pathway in the visual system of the brain, which analyses facial features. This face-perception system includes areas in the occipital and temporal lobes. Different aspects of facial information (e.g. identity and facial expression) are analysed in the ventral stream, which extends from the occipital lobe into the temporal cortex. The authors suggest that distinct areas in the face-perception system are specialized in analysing invariant and changeable aspects of faces. Invariant aspects are those facial features that form the perception of a unique identity. Changeable aspects include expression, perception of eye gaze, and lip movement. The model proposes that invariant aspects of facial information are analysed in the lateral fusiform gyrus and that changeable aspects of facial information are analysed in the superior temporal sulcus (STS). Analysing changeable aspects of faces underlies the perception of information that facilitates social communication.

Within the face, eyes are the most relevant stimuli in providing information about other people's goals, intentions, and their present focus. It is possible to judge the focus of another person's attention from the direction of their eye gaze (Baron-Cohen, 1995). In the brain, there seems to be a special eye-processing region. In their pioneering study, Perrett, Hietanen, Oram, and Benson (1992) found that in the macaque monkey brain, cells in the superior temporal sulcus (STS) and

inferotemporal cortex (IT) responded to information about the direction of attention, which was provided by body posture, head orientation, and eye gaze direction. Wicker, Michel, Henaff, and Decety (1998) used positron-emission tomography (PET) to study the areas involved in perception of gaze in the human brain. They had three different gaze conditions (straight gaze, averted gaze and eyes closed), which allowed them to distinguish the areas involved in processing the whole face from areas involved in processing the eye gaze alone. Their finding was that eye gaze activated different areas from those involved in processing other facial information. In the straight and averted gaze conditions, blood flow increased in the areas of fusiform gyrus, the right parietal lobule, right inferior temporal gyrus and middle temporal gyrus in both hemispheres. Thus it seems that perception of eyes activates a distributed network. Further evidence comes from electrophysiological studies of face perception: Event-related potential studies (Bentin, Allison, Puce, Perez, & McCarthy, 1996) have found a negative potential about 170 ms (N170) after the presentation of face and also after the presentation of eyes alone. This potential was largest over the posterior temporal scalp and it was larger in the right than the left hemisphere. More interestingly, it was larger when the eyes were presented in isolation. Bentin et al. propose that the N170 might reflect the activation of an eye-sensitive region of the cortex.

1.4. Evidence for a specific neural mechanism for reflexive attention orienting by gaze direction

For patients whose hemispheric connections have been severed (split-brain patients), stimuli can be presented separately to both hemispheres. This way it is possible to investigate how the left and right hemispheres process information. Ristic et al. (2002, experiment 3) presented non-predictive arrows to a split-brain patient and showed that the arrows produced reflexive orienting regardless of which hemisphere they were presented to. In the study by Kingstone, Friesen, and Gazzaniga (2000) non-predictive gaze cues produced reflexive attention orienting only in the face-processing hemisphere of the split-brain patients. This suggests that even though gaze cues and arrows may show similar behavioural effects of attention orienting, they may be produced by different neural mechanisms.

Kingstone, Tipper, Ristic, and Ngan (2004) studied the neural mechanisms of reflexive attention orienting using fixation stimuli, which, based on instruction, could be perceived as either a hat and eyes or as another type of directional cue, a car. Both types of stimuli produced similar behavioural shifts of reflexive attention. The authors also performed functional magnetic resonance imaging (fMRI) whilst the subjects were performing the task and they found that the neural systems underlying the two forms of attention orienting were different. In their study, the superior temporal sulcus (STS) was uniquely engaged when the stimulus was perceived as eyes. This area did not show activation when the stimulus was perceived as a car. The authors proposed that this is compelling evidence for the fact that reflexive attention orienting to gaze direction is mediated by specific neural architecture, the superior temporal sulcus. As proposed by Haxby et al. (2000), the superior temporal sulcus is part of a special pathway in the visual system of the brain which analyses facial features and thus it could also be responsible for reflexive attention orienting that is triggered by gaze direction.

1.5. Neural mechanisms of attention orienting

The focus of our attention is constantly shifting, either reflexively in response to an attention-grabbing stimulus, such as a light flash appearing in the visual periphery, or voluntarily in response to a cognitive cue, such as when searching for a friend who is wearing a red jacket in a big crowd. It has been proposed that the two forms of attention orienting, endogenous and exogenous, involve different neural pathways (e.g. Corbetta & Schulman, 2002), but the evidence is inconclusive. Magnetic resonance imaging (MRI) studies of Rosen et al. (1999) and positron-emission tomography (PET) studies of Corbetta, Miezin, Schulman, and Petersen (1993) and Nobre et al. (1997) failed to find different neural systems for the two forms of attention orienting. In their studies, endogenous and exogenous attention tasks activated overlapping regions in parietal cortices. On the other hand, Corbetta and Schulman (2002) propose in their review article that goal-directed, voluntary attention orienting is subserved by neural mechanisms in the intraparietal cortex and superior frontal cortex. Reflexive attention orienting, on the other hand, is largely lateralized to the right hemisphere and includes the temporoparietal cortex and inferior frontal cortex.

1.6. Event-related potentials and attention orienting

Event-related potential (ERP) recordings have been used in the study of attention for over 30 years (for a review see Luck, Woodman, & Vogel, 2000). The classic ERP paradigm that is used in the study of exogenous visual attention consists of comparing ERP waveforms elicited by stimuli presented in incongruent and congruent locations (Luck et al., 2000). The spatial-cuing studies with central and peripheral cues have shown amplitude enhancements in both the occipital P1 and parieto-occipital N1 components in congruent trials (Luck et al., 1994; Mangun & Hillyard, 1991). The P1 wave is a positive deflection whose onset is about 70-100 ms post-stimulus. The onset of the N1 wave is about 150-200 ms post-stimulus. The observed amplitude modulations indicate that the enhanced speed and accuracy observed in behavioural reaction times are at least partially caused by enhanced sensory processing. Dipole modelling studies of the P1 and N1 waves have located their neural generator sources in lateral extrastriate cortex (Clark & Hillyard, 1996; Gomez Gonzales, Clark, Fan, Luck, & Hillyard, 1994). This shows that reflexive attention is able to affect perceptions of the visual world by modulating neural processing as early as the visual extrastriate cortex (Hopfinger & Mangun, 1998).

Schuller and Rossion (2001) recorded ERP's to study the neural correlates of reflexive shifts of attention triggered by dynamic eye gaze direction. They found enhanced and earlier occipito-parietal P1 and N1 components for valid trials, thus demonstrating that allocation of attention modulates visual input very early and that attention triggered by social cues rapidly modifies the processing of a visual target in extrastriate cortex. More recently, Schuller and Rossion (2004) investigated whether static gaze cues elicit similar early sensory modulations. They wanted to rule out the possibility that the sensory modulations observed earlier (Schuller & Rossion, 2001) were caused by visual motion cues and not the gaze direction itself. They also explored whether the attention orienting effects they found earlier reflected facilitation of the processing of cued stimuli, inhibition of unattended stimuli or both. In their study, early ERP components, the occipital P1 and occipito-temporal N1 were modulated by social attention allocation. The P1 component was speeded up as early as ~100 ms after stimulus onset. The P1 and N1 components were enhanced in response to congruent trials, especially in the right hemisphere. Gaze cue facilitated

the processing of cued stimuli and did not inhibit the processing of unattended stimuli. These observations prove that early visual processing is speeded up and amplified following attention orienting triggered by static eye gaze perception. The effects are largely lateralized to the right hemisphere. Thus it is obvious that social attention can rapidly modify visual processing of stimuli at an early sensory stage.

Predictive cueing with symbolic tasks have generally been characterized by amplitude modulations only (for a review see Luck et al. 2000) and have lacked latency effects observed in eye gaze cuing studies (however, see Di Russo & Spinelli, 1999). In his study with symbolic arrow cues, Eimer (1997) found larger N1 and N2 potentials for cued locations with both predictive and unpredictable cues. These effects were observed at midline electrodes. As far as the author of the present study is aware, the effects of attention orienting on event-related potentials by non-predictive eye gaze cues and symbolic arrow cues have never been directly compared in the same study.

1.7. Aims of the study

The present study investigates the neural mechanisms underlying reflexive attention orienting with two different stimulus categories: socially and biologically relevant gaze direction cues and symbolic cues, arrows. The study will measure neural activity in human subjects using the event-related potential (ERP) method. In most behavioural studies, both eye gaze (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Langton & Bruce, 1999; Ristic et al. 2002), and arrow cues (Ristic et al., 2002; Tipples, 2002) have produced reflexive attention orienting effects. This has been interpreted so that both eye gaze and arrows can trigger reflexive attention orienting (Ristic et al., 2002; Tipples, 2002). However, although eye gaze may not be a unique stimulus in triggering reflexive attention orienting, it may nevertheless trigger a more reflexive type of attention orienting than arrows do (Friesen & Kingstone, 2004). The neural activity evoked by reflexive attention orienting triggered by gaze direction and arrows may be different.

Previous behavioural studies with eye gaze cues (Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003; Schuller & Rossion, 2004) have found that whilst attention orienting following eye gaze cues results in targets being detected faster in

congruent than in incongruent or neutral trials, there is no significant difference in reaction times between incongruent and neutral trials. This has been interpreted as facilitation in processing of congruent targets without there being any cost in processing of incongruent targets. This question has not previously been explored with arrow cues. The present study aims to explore whether also with arrow cues, a similar benefit effect in processing of congruent targets, without a cost in processing of incongruent targets, will be found.

In ERP-studies, gaze direction cues have been shown to result in shorter latencies and enhanced amplitudes of the visual components, especially in the right hemisphere (Schuller & Rossion, 2001, 2004). Generally, predictive and unpredictable symbolic cues have lacked the latency effects and have only shown the amplitude effects (Eimer, 1997; Luck et al., 1994, 2000; Mangun & Hillyard, 1991). The present study will record event-related potentials and compare the effects of attention orienting by gaze direction and arrow cues on the latencies and amplitudes of the visual P1 and N1 components.

2. Methods

2.1. Subjects

Nineteen introductory psychology students (4 males, 4 left handed, age range 19-26 years, mean 22 years) took part in the experiment. Data from one male participant had to be discarded from analysis because of uncorrected abnormal vision acuity in one eye. All remaining participants reported normal or corrected to normal vision. All participants were unaware of the purpose of the experiment.

2.2. Stimuli and procedures

Participants were seated in a comfortable chair in a dimly lit room, at a distance of 77 cm from a computer screen. They had to fixate on a simple, black cross ($0.4^\circ / 0.4^\circ$) in the centre of the computer screen (Nokia 930C 17" monitor, 75 Hz refresh rate). Two kinds of cue stimuli were used in the experiment. They were either pictures of a schematic face with eyes gazing either left, right or forward, or pictures of an arrow directed to left or right or a straight line. In instruction, the participants were told that the stimuli they would be seeing were faces and "traffic signs". Figure 1 shows the

types of cue stimuli used in the experiment. An asterisk ($0.4^\circ/0.4^\circ$) was used as a target. The round outline of the schematic faces and the traffic signs subtended a visual angle of 10.0° . The eyes of the schematic faces subtended a visual angle of 1.5° . Pupils measured a visual angle of 0.7° . The arrows and the straight line in the traffic signs measured a visual angle of 0.6° vertically and 6.7° horizontally.

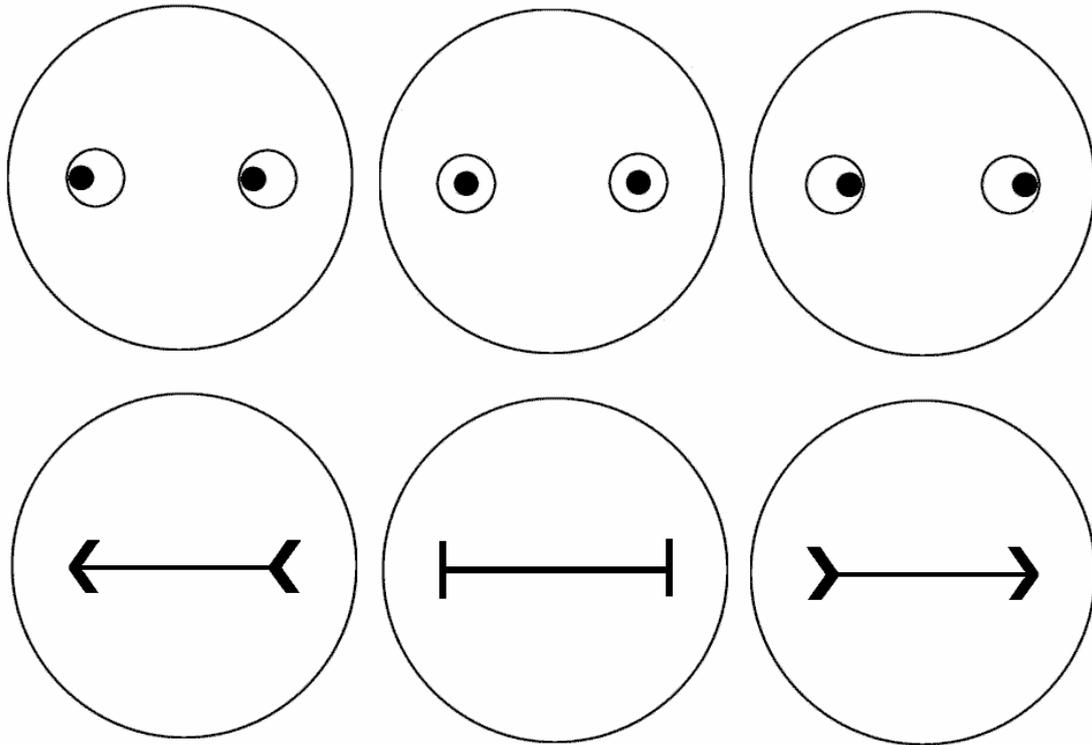


Fig. 1. Cue stimuli used in the experiment.

A trial was made of the following events: first, the fixation point appeared on the computer screen. Then, after 1000 ms, the fixation point was replaced by a cue stimulus that was either a face with eyes gazing left, right or forward, or an arrow pointing towards left or right or a straight line. The fixation point was located at eye level between the eyes or at the level of the arrow in the middle of it. 500 ms after the appearance of the cue, a target stimulus appeared either congruently (on the same side), incongruently (on the opposite side) or neutrally (after a face looking forward or after a straight line) with respect to the cue. The target appeared at a distance of 7.0° of visual angle from the fixation point. The cue and the target stimuli remained on the screen until the participant's response. The next trial was presented after a 500-ms delay.

The experiment consisted of 10 blocks of trials (5 blocks of face trials and 5 blocks of arrow trials) with a rest between each block. Each block was randomly composed of 30 congruent, 30 incongruent and 30 neutral trials. The blocks also included catch trials where no target followed the cue. Blocks of faces and arrows were always presented so that a block consisting of faces was followed by a block consisting of arrows. A half of the participants started with a block of faces and a half of them with a block of arrows. Participants were required to press a button on the response box (Neuroscan Stim System Switch Response Pad P/N 1141) using their dominant hand when they detected the appearance of the target stimulus. No discrimination was required. They were asked to respond as fast as possible and to refrain from pressing the button on catch trials. Catch trials made up 10 % of the total number of trials in each block. They were constructed so that a new trial started 1000 ms after the presentation of the cue stimulus. Catch trials were presented in order to maintain the attention of participants during the experiment and to prevent anticipatory button presses. 18 trials were run before starting the experiment to familiarize the participants with the task. Participants were informed that the direction of the eye gaze or the arrow did not predict the location of the following target.

2.3. Event-related potential recordings and data analysis of event-related potentials

The EEG was recorded from 64 electrodes in an elastic cap (Electro-Cap International, inc.) and referenced to the tip of the nose during recording. The electrodes were allocated using the standard locations of the International 10-20 system. Electrode impedances were maintained below 5 k Ω . Horizontal eye movements were monitored by two electrodes at the outer canthi of the eyes referenced to each other. Vertical eye movements and eye blinks were detected by electrodes placed above and below the right eye. EEG was amplified with a gain of 500 K and bandpass filtered between 0.05 and 100 Hz (Syn-Amps 4.3, Neuroscan, Inc.). The EEG was filtered off-line between 2 Hz and 20 Hz. The raw signal was digitized with a sampling rate of 1000 Hz. Blink artefacts were corrected by a VEOG correction method (Syn-Amps 4.3, Neuroscan, Inc.). Averages were generated for each subject and each of the conditions in epochs of -100 to 500 ms. One participant's data had to be discarded from analysis because electrode impedances

were not at a satisfying level during the whole recording period. Therefore EEG data were analysed from 17 participants.

2.4. Data analysis

Following visual inspection of scalp topography of grand averaged data across all participants in different conditions, peak latencies and amplitudes of the visual P1 and N1 components were extracted automatically for each participant in each condition on electrodes P5, P6, P3, P4, PO7, PO6, PO5, PO4, O1 and O2. Repeated-measures analyses of variance (ANOVA) and planned mean comparisons were performed on RT and ERP measurements. Greenhouse-Geisser correction was used to correct p-values for factors containing more than two levels. After inspecting the grand analysis of ERP data with the electrode pairs P5/P6, P3/P4, PO7/PO6, PO5/PO4 and O1/O2, electrodes P3, P4, P5 and P6 were chosen for further analysis.

3. Results

3.1. Behavioural reaction times

The false alarm rate on catch trials was 10.9%. Reaction times (RT) that were shorter than 100 ms and longer than 1000 ms were excluded from analysis. A mean response time and standard deviation was calculated for every participant's data across all conditions. Reaction times that were either longer than 2 standard deviations above or shorter than 2 standard deviations below the mean were treated as outliers and were excluded from the data analysis. These procedures resulted in the exclusion of 4.4 % of the trials. After this, a mean reaction time for both cue types in each condition and with target being presented in the right visual field and left visual field (arrow or gaze cue, congruent, incongruent or neutral condition, right vs. left visual field presentation of target) was calculated. These data were analysed using a three-way (cue X congruency X laterality of target) repeated-measures analysis of variance (ANOVA). This analysis showed significant main effects of cue [$F(1,17) = 23.1, p < .001$], congruency [$F(1.5, 25.7) = 22.2, p < .001$] and laterality [$F(1,17) = 4.6, p < .05$]. There was no significant interaction between any of these variables. The main effect of cue type indicated that targets were detected faster after the presentation of an arrow (261ms) than a gaze (269 ms) as a cue. The main effect of congruency indicated that targets were detected at different speeds in congruent (257 ms),

incongruent (270 ms) and neutral (268 ms) locations. The main effect of laterality of targets indicated that targets appearing in the right visual field were detected faster (262 ms) than targets appearing in the left visual field (267 ms). Table 1 presents reaction times for gaze and arrow cue stimuli in congruent, incongruent and neutral trials, that have been averaged over the factor laterality of target presentation.

Table 1. Reaction times in milliseconds for arrow and gaze cue stimuli in congruent, incongruent and neutral trials.

	<i>Trial type</i>					
	<i>Congruent</i>		<i>Incongruent</i>		<i>Neutral</i>	
<i>Cue type</i>	<u><i>M</i></u>	<u><i>SD</i></u>	<u><i>M</i></u>	<u><i>SD</i></u>	<u><i>M</i></u>	<u><i>SD</i></u>
<i>Arrow</i>	253	25	264	32	264	32
<i>Gaze</i>	261	29	275	32	271	31

The effect of congruency was analysed further with paired-comparisons. In order to confirm that the pattern of results between different cuing conditions was the same for the gaze and arrow cues, the data for gaze and arrow cues were analysed separately. Paired-samples t-tests showed that targets were detected significantly faster in congruent arrow trials (254 ms) when compared to incongruent arrow trials (264ms) [$t(17) = -3.7, p < .05$] and neutral arrow trials (264 ms) [$t(17) = -4.8, p < .01$]. There was no significant difference in the detection of targets in incongruent and neutral arrow trials [$t(17) = 0.2, p = .814$]. Also, targets were detected significantly faster in congruent gaze trials (261ms) when compared to incongruent gaze trials (275ms) [$t(17) = -5.6, p < .001$] and neutral gaze trials (271ms) [$t(17) = -7.1, p < .001$]. There was no significant difference in the detection of targets in incongruent and neutral gaze trials [$t(17) = 1.7, p = .108$].

3.2. Event-related potentials

3.2.1. Grand analysis

A five-way (cue X congruency X laterality of target appearance (later on referred to simply as “laterality”) X hemisphere X electrode site) analysis of variance (ANOVA) was performed on the P1 and N1 latency and amplitude data of electrode pairs P5 /P6, P3/P4, PO7/PO6, PO5/PO4 and O1/O2. Electrodes P5, P3, PO7, PO5 and PO1 were situated over the left hemisphere and electrodes P6, P4, PO6, PO4 and O2 over the right hemisphere.

3.2.1.1. P1 latency

A significant main effect of cue [$F(1,16) = 15.2, p < .001$] indicated that the P1 component peaked earlier following a gaze (121 ms) than an arrow (123 ms) cue. The main effect of laterality of target presentation [$F(1,16) = 13.9, p < .01$] indicated that P1 peaked earlier when targets were presented in the right visual field (RVF) (119 ms) than in the left visual field (LVF) (125 ms). The main effect of hemisphere [$F(1,16) = 14.5, p < .01$] indicated that the P1 peaked earlier in the left (119 ms) than in the right (125 ms) hemisphere. There was also a main effect of electrode site [$F(2,1, 34.3) = 8.3, p < .001$], which indicated that P1 peaked at different speed on different electrodes. P1 peaked at 121 ms on electrode-pair P5/P6, at 120 ms on P3/P4, at 123 ms on PO7/PO6, at 122 ms on PO5/PO4 and at 125 ms on O1/O2. The main effect of congruency was not significant. There were no significant interactions.

3.2.1.2. P1 amplitude

On the P1 amplitude, there were significant main effects of laterality, electrode site and hemisphere. The main effect of congruency was not significant. The main effect of laterality [$F(1,16) = 5.4, p < .05$] indicated that the P1 amplitude was larger when targets were presented in the LVF (1.9 mV) than in the RVF (1.5 mV). The main effect of hemisphere [$F(1,16) = 7.7, p < .05$] indicated that the P1 amplitude was larger in the right (1.9 mV) than in the left (1.5 mV) hemisphere. The main effect of electrode site [$F(1,3, 21.4) = 9.3, p < .01$] indicated that there were significant differences in amplitudes on different electrode pairs. The P1 amplitude was 1.5 mV on the electrode pair P5/P6, 1.2 mV on P3/P4, 2.0 mV on PO7/PO6, 1.8 mV on PO5/PO4 and 1.9 mV on O1/O2. There was also a significant interaction of cue and congruency [$F(1,16) = 5.4, p < .05$]. There were no other significant interactions.

3.2.1.3. N1 latency

On the N1 latency, there were significant main effects of cue, electrode site and hemisphere. The main effect of congruency was not significant. The main effect of cue [$F(1,16) = 5.2, p < .05$] indicated that the N1 peaked earlier after gaze (175 ms) than after arrow (180 ms) cues. The main effect of hemisphere [$F(1,16) = 9.6, p < .01$] indicated that the N1 peaked earlier in the left (172 ms) than in the right (179 ms) hemisphere. The main effect of electrode site [$F(1,4, 22.4) = 14.4, p < .001$] indicated

that there were significant differences in the latencies of the N1 component on the different electrode pairs. The N1 peaked at 173 ms on electrode pair P5/P6, at 172 ms on P3/P4, at 178 ms on PO7/PO6, at 176 ms on PO5/PO4 and at 179 ms on O1/O2. There were significant interactions between laterality and hemisphere [$F(1,16) = 38.5$, $p < .001$] and between site and hemisphere [$F(2.7, 89.4) = 3.8$, $p < .05$] and between laterality, electrode site and hemisphere [$F(2.1, 32.8) = 10.0$, $p < .001$]. There was also a significant interaction between laterality, congruency and hemisphere [$F(1,16) = 6.2$, $p < .05$].

3.2.1.4. N1 amplitude

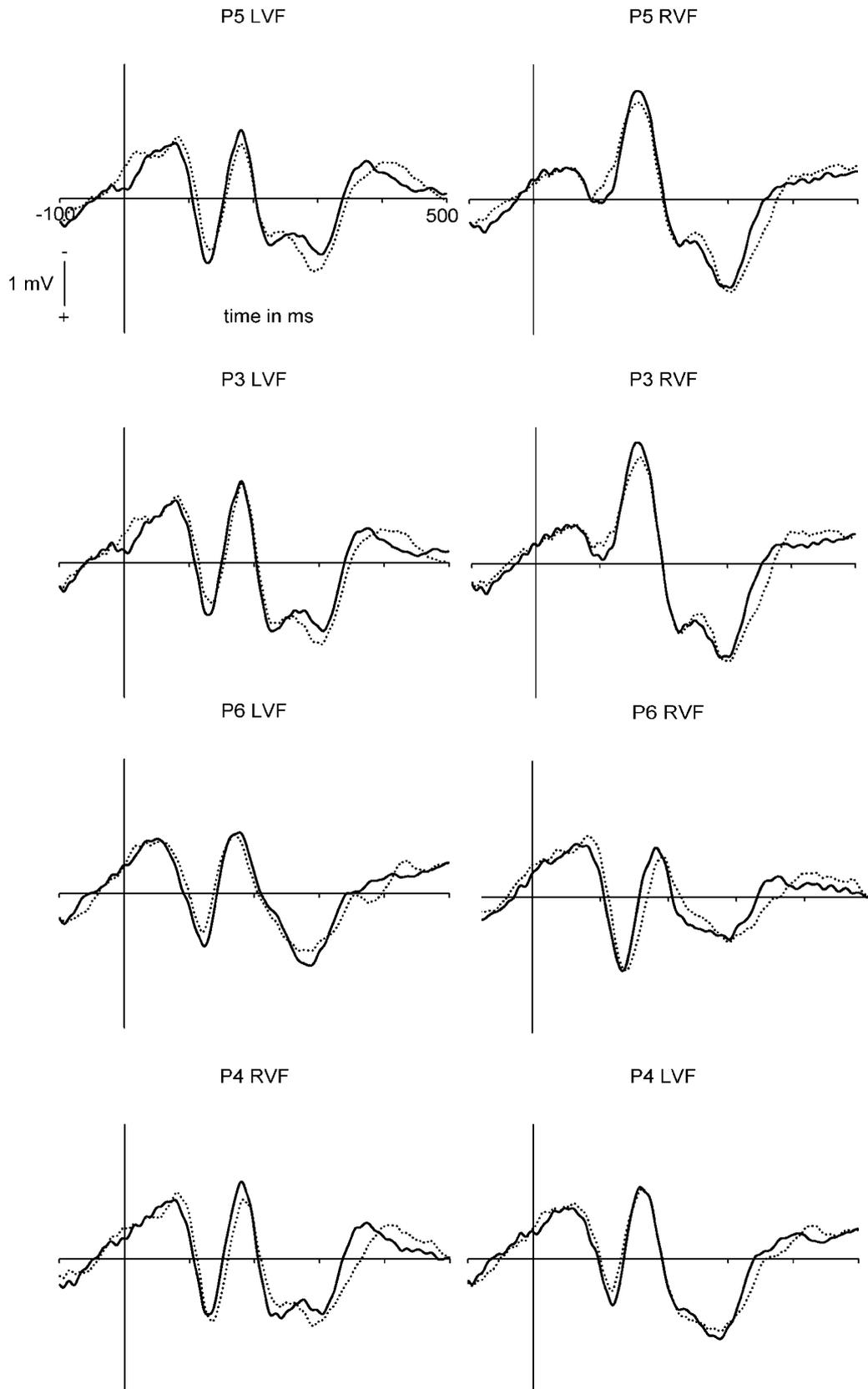
On the N1 amplitude, there was a significant main effect of hemisphere [$F(1,16) = 7.6$, $p < .05$], which indicated that the N1 was larger in the left (-2.6 mV) than in the right (-2.1 mV) hemisphere. There were also significant interactions between cue, laterality and electrode site [$F(2.1, 33.2) = 5.9$, $p < .01$], congruency and electrode site [$F(1.9, 30.6) = 3.4$, $p < .05$], laterality and hemisphere [$F(1,16) = 10.1$, $p < .01$] and laterality, electrode site and hemisphere [$F(3.0, 47.2) = 8.2$, $p < .001$].

3.2.2. Analysis of electrodes P5, P3, P6 and P4

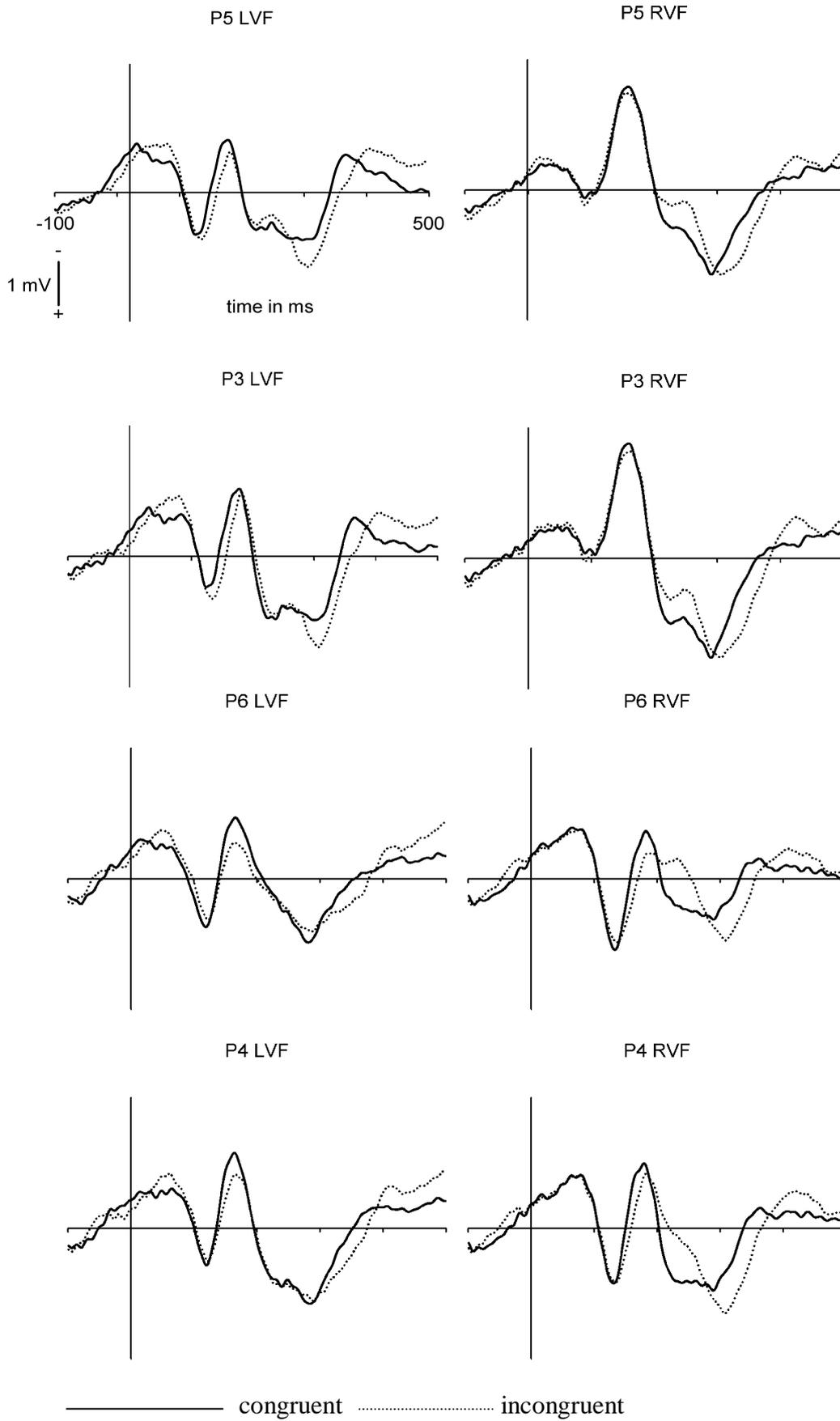
After inspecting the grand analysis with the electrode pairs P5/P6, P3/P4, PO7/PO6, PO5/PO4 and O1/O2, the most prominent looking electrodes P5, P3, P4 and P6 were chosen for further analysis. A three-way (cue X congruency X laterality) analysis of variance (ANOVA) was performed separately for each electrode and for all four dependent variables: P1 latency, P1 amplitude, N1 latency and N1 amplitude. Figure 2 presents plots of the grand-averaged ERP waveforms for each of the four electrodes. Different plots were drawn according to visual field of target presentation (LVF trials for where the target was presented in the left visual field and RVF trials for where the target was presented in the right visual field).

Fig. 2. Grand-averaged ERP-waveforms for congruent and incongruent trials on electrodes P5, P3 (left hemisphere), P6 and P4 (right hemisphere). LVF refers to trials where the target appeared in the left visual field and RVF to trials where the target appeared in the right visual field. Black lines represent ERPs in congruent trials and dotted lines represent ERPs in incongruent trials.

Arrow Trials



Gaze trials



3.2.2.1. P1latency

Table 2 presents the results of analyses of variances (F-and p-values) of P1 latency on all four electrodes.

Table 2. F- and p-values of P1 latency on electrodes P5, P3, P4 and P6.

Abbreviations: elect. = electrode, congr. = congruency, lat. = laterality, n.s. = not significant

<i>elect.</i>	<i>congr.</i>	<i>cue</i>	<i>laterality</i>	<i>congr. x cue</i>	<i>congr. x lat.</i>	<i>cue x lat.</i>	<i>congr. x cue x lat.</i>
<i>P5</i>	F=1.03 p=n.s.	F =5.80 p<.050	F =80.32 p<.001	F=0.48 p=n.s.	F=1.98 p=n.s.	F=0.49 p=n.s.	F=0.50 p=n.s.
<i>P3</i>	F=0.23 p=n.s.	F=1.59 p=n.s.	F=72.69 p<.001	F=0.07 p=n.s.	F=1.98 p=n.s.	F=2.38 p=n.s.	F=0.47 p=n.s.
<i>P6</i>	F=5.79 p<.050	F=3.88 p<.070	F=26.39 p<.001	F=0.11 p=n.s.	F=0.92 p=n.s.	F=0.64 p=n.s.	F=0.45 p=n.s.
<i>P4</i>	F=4.18 p<.060	F=1.11 p=n.s.	F=21.65 p<.001	F=1.44 p=n.s.	F=0.19 p=n.s.	F=0.50 p=n.s.	F=0.01 p=n.s.

On electrode P5 there were significant main effects of cue [$F(1,16) = 5.8, p < .05$] and laterality [$F(1,16) = 80.3, p < .001$]. These effects indicated that the P1 component peaked significantly earlier after the presentation of a gaze (115 ms) than after an arrow (118 ms) cue. The P1 peaked significantly earlier in trials where the target was presented in the RVF (103 ms) than in the LVF (130 ms).

On electrode P3, the only significant main effect was that of laterality [$F(1,16) = 72.7, p < .001$], which indicated that the P1 peaked earlier in trials where the target was presented in the RVF (104 ms) than in the LVF (129 ms).

On electrode P6 there were significant main effects of congruency [$F(1,16) = 5.7, p < .05$] and laterality [$F(1,16) = 26.4, p < .001$]. The main effect of cue also approached significance [$F(1,16) = 3.9, p = .067$]. These effects indicated that the P1 peaked significantly earlier in congruent (123 ms) than in incongruent (127 ms) trials and that it peaked earlier when targets were presented in the LVF (119 ms) than in the RVF (131 ms). The main effect of cue, which approached significance, indicated that the P1 peaked earlier in gaze (124 ms) than in arrow (126 ms) trials.

On electrode P4 there was a significant main effect of laterality [$F(1,16) = 21.7, p < .001$] which indicated that the P1 peaked earlier when targets were presented in the LVF (117 ms) than in the RVF (130 ms). The main effect of congruency approached significance [$F(1,16) = 4.2, p = .058$], indicating that P1 peaked earlier in congruent (122) than in incongruent (125 ms) trials.

3.2.2.2. P1 amplitude

Table 3 presents the results of analyses of variances (F- and p-values) of P1 amplitude on all four electrodes.

Table 3. F- and p-values of P1 amplitude on electrodes P5, P3, P4 and P6. Abbreviations: elect. =electrode, congr. = congruency, lat. = laterality, n.s. = not significant

<i>elect.</i>	<i>congr.</i>	<i>cue</i>	<i>laterality</i>	<i>congr. x cue</i>	<i>congr. x lat.</i>	<i>cue x lat.</i>	<i>congr x cue x lat.</i>
<i>P5</i>	F=1.02 p=n.s.	F=0.03 p=n.s.	F=13.7 p<.010	F=7.23 p<.050	F=0.15 p=n.s.	F=6.66 p<.050	F=0.35 p=n.s.
<i>P3</i>	F=0.11 p=n.s.	F=0.14 p=n.s.	F=16.51 p<.001	F=10.12 p<.010	F=1.09 p=n.s.	F=2.77 p=n.s.	F=0.70 p=n.s.
<i>P6</i>	F=1.05 p=n.s.	F=0.02 p=n.s.	F=5.73 p<.050	F=0.55 p=n.s.	F=2.87 p=n.s.	F=0.67 p=n.s.	F=1.93 p=n.s.
<i>P4</i>	F=0.09 p=n.s.	F=0.33 p=n.s.	F=3.88 p<.070	F=2.76 p=n.s.	F=8.55 p<.010	F=0.69 p=n.s.	F=1.23 p=n.s.

On electrode P5, there was a significant main effect of laterality [$F(1,16) = 13.6, p < .01$] which indicated that the P1 was enhanced in trials where targets were presented in the LVF (1.6 mV) compared with trials where targets were presented in RVF (0.7 mV). There were also significant interactions between cue and laterality [$F(1,16) = 6.7, p < .05$] and between cue and congruency [$F(1,16) = 7.2, p < .05$]. Paired t-tests showed that the P1 was larger in congruent arrow (2.3 mV) than in incongruent arrow trials (0.9 mV) [$t(16) = 4.4, p < .001$]. The difference between congruent and incongruent gaze trials was not significant. The P1 amplitude was enhanced in congruent arrow trials (2.3 mV) when compared to congruent (1.1 mV) gaze trials [$t(16) = 4.6, p < .001$]. As for the interaction of cue and laterality, P1 was larger in arrow trials, where the target was presented in the LVF (1.7 mV) in comparison with arrow trials, where the target was presented in the RVF (0.6 mV) [$t(16) = -4.4, p <$

.001]. A similar effect was found on gaze trials: P1 was larger in LVF gaze trials (1.5 mV) than in RVF gaze trials (0.8 mV) [$t(16) = 2.7, p < .05$]. In RVF trials, P1 was larger in gaze (0.8 mV) than in arrow trials (0.6 mV) [$t(16) = -2.6, p < .05$]. In LVF trials there were no significant effects of this kind.

On electrode P3 there was a main effect of laterality [$F(1,16) = 16.5, p < .001$], which indicated that the P1 was enhanced when targets were presented in the LVF (1.4 mV) in comparison with trials where targets were presented in the RVF (0.4 mV). There was also a significant interaction between cue and congruency [$F(1,16) = 10.1, p < .01$]. Paired analysis of the variables indicated that the P1 was larger in congruent (1.1 mV) than in incongruent (0.75 mV) arrow trials and this approached significance [$t(16) = 2.0, p = .057$]. A reverse effect was found on gaze trials, the P1 was larger in incongruent (1.0 mV) than in congruent (0.7 mV) gaze trials and this also approached significance [$t(16) = -2.1, p = .057$]. The P1 was larger in congruent arrow (1.1 mV) trials than in congruent gaze (0.7 mV) trials [$t(16) = 2.1, p = .051$].

On electrode P6 there was a significant main effect of laterality [$F(1,16) = 5.7, p < .05$], which indicated that the P1 was larger in trials where the target was presented in the RVF (2.0 mV) than in the LVF (1.5 mV).

On electrode P4 there was a significant interaction between laterality and congruency [$F(1,16) = 8.6, p < .01$]. Paired-analysis comparisons showed that P1 was larger in incongruent trials where the target was presented in the RVF (1.8 mV) in comparison to incongruent trials where the target was presented in the LVF (1.2 mV) [$t(16) = -2.6, p < .05$].

3.2.2.3. N1 latency

Table 4 presents the results of analyses of variances (F- and p-values) on N1 latency.

Table 4. F- and p-values of N1 latency on electrodes P5, P3, P4 and P6.
Abbreviations: elect. = electrode, congr. =congruency, lat. = laterality, n.s. = not significant

<i>elect.</i>	<i>congr.</i>	<i>cue</i>	<i>laterality</i>	<i>congr. x cue</i>	<i>congr. x lat.</i>	<i>cue x lat.</i>	<i>congr x cue x lat.</i>
<i>P5</i>	F=1.81 p=n.s.	F=7.85 p<.050	F=41.90 p<.001	F=5.25 p<.050	F=1.33 p=n.s.	F=0.95 p=n.s.	F=0.003 p=n.s.
<i>P3</i>	F=8.34 p<.010	F=4.02 p<.070	F=39.77 p<.001	F=1.81 p=n.s.	F=1.29 p=n.s.	F=0.05 p=n.s.	F=0.19 p=n.s.
<i>P6</i>	F=0.33 p =n.s.	F=8.90 p<.010	F=19.40 p<.001	F=2.21 p=n.s.	F=4.04 p<.070	F=4.37 p<.060	F=1.72 p=n.s.
<i>P4</i>	F=4.13 p<.060	F=4.11 p<.060	F=16.30 p<.001	F=0.69 p=n.s.	F=5.04 p<.040	F=1.01 p=n.s.	F=1.16 p=n.s.

On electrode P5 there were significant main effects of cue and laterality. The main effect of cue [$F(1,16) = 7.9, p < .05$] indicated that the N1 peaked significantly earlier in gaze (168 ms) than in arrow (170 ms) trials. The main effect of laterality [$F(1,16) = 41.9, p < .001$] indicated that the N1 peaked significantly earlier in trials where the target was presented in the RVF (160 ms) than in the LVF (178 ms). There was also a significant interaction between cue and congruency [$F(1,16) = 5.3, p < .05$]. This was further examined with paired analysis t-tests which showed that the N1 peaked significantly earlier in congruent (166 ms) than in incongruent (170 ms) gaze trials [$t(16) = -2.4, p < .05$]. The N1 peaked earlier in congruent gaze (166 ms) than in congruent arrow (170 ms) trials [$t(16) = 2.9, p < .01$].

On electrode P3 there were significant main effects of laterality [$F(1,16) = 39.8, p < .001$] and congruency [$F(1,16) = 8.3, p < .01$]. The main effect of laterality indicated that the N1 peaked significantly earlier when the target was presented in the RVF (162 ms) than in the LVF (177 ms). The main effect of congruency indicated that the N1 peaked significantly earlier in congruent (168 ms) than in incongruent (171 ms) trials. The main effect of cue also approached significance [$F(1,16) = 4.0, p = .062$] indicating that the N1 peaked earlier in gaze (168 ms) than in arrow (171 ms) trials.

On electrode P6 there were significant main effects of cue and laterality. The main effect of cue [$F(1,16) = 8.9, p < .01$] indicated that the N1 peaked significantly earlier in gaze (176 ms) than in arrow (180 ms) trials. The main effect of laterality [$F(1,16) =$

19.4, $p < .001$] indicated that the N1 peaked earlier in trials where the target was presented in the LVF (171 ms) than in the RVF (184 ms). There were also two interactions that approached significance. They were those of cue and laterality [$F(1,16) = 4.4$, $p = .053$] and laterality and congruency [$F(1,16) = 4.0$, $p = .062$]. These were further analysed with paired samples t-tests. On arrow trials, the N1 peaked earlier in trials where the target was presented in the LVF (175 ms) than in the RVF (185 ms) [$t(16) = -3.7$, $p < .01$]. On gaze trials a similar effect was found: the N1 peaked earlier in trials where the target was presented in the LVF (168 ms) than in those trials where the target was presented in the RVF (184 ms). N1 peaked significantly earlier in gaze trials where the target was presented in the LVF (168 ms) than in similar arrow trials (175 ms) [$t(16) = 3.1$, $p < .01$]. In trials where the target was presented in the RVF, a similar tendency was observed but it was not significant. As for the interaction of laterality and congruency, N1 peaked earlier in congruent LVF (173 ms) than in congruent RVF (184 ms) trials [$t(16) = -3.9$, $p < .001$]. A similar effect was found in incongruent LVF (170 ms) and RVF (185 ms) trials [$t(16) = 4.3$, $p < .001$].

On electrode P4 there was a significant main effect of laterality [$F(1,16) = 16.3$, $p < .001$], which indicated that the N1 peaked earlier in trials where the target that was presented in the LVF (170 ms) than in the RVF (181 ms). There were also two significant main effects, those of cue and congruency, which approached significance. The main effect of cue [$F(1,16) = 4.1$, $p = .060$] indicated that the N1 peaked earlier after gaze (174 ms) than after arrow (177 ms) cues. The main effect of congruency [$F(1,16) = 4.1$, $p = .059$] indicated that the N1 peaked earlier in congruent (174 ms) than in incongruent (176 ms) trials. There was also a significant interaction of laterality and congruency [$F(1,16) = 5.0$, $p < .05$]. Paired analysis t-tests showed that N1 peaked earlier in congruent RVF (179 ms) than in incongruent RVF (183 ms) trials [$t(16) = -3.3$, $p < .01$]. However, the N1 peaked earlier in congruent LVF (170 ms) than in congruent RVF (179 ms) trials [$t(16) = -3.4$, $p < .01$]. It also peaked earlier in incongruent LVF (170 ms) than in incongruent RVF trials (183 ms) [$t(16) = -4.3$, $p < .001$]. The LVF dominance was so strong, that the N1 peaked earlier in incongruent LVF (170 ms) than in congruent RVF (179 ms) trials [$t(16) = -3.0$, $p < .01$].

3.2.2.4. N1 amplitude

Table 5 presents the results of analyses of variances (F- and p-values) of N1 amplitude.

Table 5. F- and p-values of N1 amplitude on electrodes P5, P3, P4 and P6. Abbreviations: elect. = electrode, congr. =congruency, lat. = laterality, n.s. = not significant

<i>elect.</i>	<i>congr.</i>	<i>cue</i>	<i>laterality</i>	<i>congr. x cue</i>	<i>congr. x lat.</i>	<i>cue x lat.</i>	<i>congr x cue x lat.</i>
<i>P5</i>	F4.47 p<.050	F=1.40 p= n.s.	F=21.61 p<.001	F=0.01 p=n.s.	F=0.64 p=n.s.	F=0.87 p=n.s.	F=1.04 p= n.s.
<i>P3</i>	F=0.81 p=n.s.	F=0.80 p=n.s.	F=12.06 p< .010	F=0.01 p=n.s.	F=0.15 p=n.s.	F=0.49 p=n.s.	F=3.30 p<.090
<i>P6</i>	F=3.27 p<.090	F=1.09 p=n.s.	F=4.38 p<.060	F=0.05 p=n.s.	F=0.01 p=n.s.	F=0.32 p=n.s.	F=0.99 p=n.s.
<i>P4</i>	F=0.34 p=n.s.	F=0.36 p=n.s.	F=2.43 p=n.s.	F=0.10 p=n.s.	F=0.22 p=n.s.	F=0.26 p=n.s.	F=2.63 p=n.s.

On electrode P5 there were significant main effects of laterality and congruency. The main effect of laterality [$F(1,16) = 21.6, p < .001$] indicated that the N1 was enhanced in trials where the target was presented in the RVF (-3.1 mV) in comparison with trials where the target was presented in the LVF (-2.0 mV). The significant main effect of congruency [$F(1,16) = 4.5, p < .05$] indicated that the N1 was enhanced in congruent (-2.7 mV) in comparison to incongruent (-2.4 mV) trials.

On electrode P3 there was a significant main effect of laterality [$F(1,16) = 12.1, p < .01$], which indicated that the N1 was enhanced in trials where the target was presented in the RVF (-3.3 mV) than in trials where the target was presented in the LVF (-2.5 mV).

On electrode P6 there was a nearly significant main effect of laterality [$F(1,16) = 4.4, p = .053$] which indicated that the N1 was enhanced in trials where the target was presented in the LVF (-2.4 mV) when compared with trials where the target was presented in the RVF (-1.8 mV). The main effect of congruency also approached significance [$F(1,16) = 3.3, p = .089$] indicating that the N1 was larger in congruent (-2.3 mV) than in incongruent (-1.9 mV) trials.

On electrode P4 there were no significant main effects or interactions.

4. Discussion

The purpose of this study was to compare the effects of attention orienting using two kinds of stimuli: socially and biologically relevant eye gaze cues and symbolic arrow cues. In order to achieve this, behavioural and EEG data were collected and analysed.

4.1. Behavioural effects of eye gaze and symbolic cuing

Confirming previous behavioural observations, both eye gaze (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Hietanen & Leppänen, 2003; Langton & Bruce, 1999; Ristic et al., 2002) and symbolic arrow cues (Ristic et al., 2002; Tipples, 2002) triggered reflexive attention orienting. Targets that appeared in congruent locations were detected faster than targets that appeared in incongruent and neutral locations, despite subjects being told that eye gaze and arrow cues were non-predictive of the upcoming target. Targets in neutral trials were detected at the same speed as targets in incongruent trials. This confirmed that attention orienting following eye gaze is mainly expressed as a benefit effect (Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003; Schuller & Rossion, 2004), which means that cuing speeds up the response to a target in a congruent location without slowing down the response to an incongruent target. A novel finding was a similar benefit effect on arrow trials. The reaction times in congruent arrow trials were significantly shorter than reaction times in incongruent and neutral arrow trials. There was no significant difference in reaction times in incongruent and neutral trials indicating that attention orienting following symbolic cues such as arrows is also expressed as facilitation of the processing of a target in a congruent location without any cost in the processing of a target in an incongruent location.

In the present study, targets were detected faster in arrow than in gaze trials. Ristic et al. (2002, exp.1 and 2) didn't find any significant main effects of cue type when comparing reflexive orienting to gaze and arrow cues in either adults or preschool children. At this point it is difficult to find an explanation for this pattern of results.

Subjects detected targets that appeared in the right visual field faster than targets appearing in the left visual field. Faster detection of targets appearing in the right visual field could be due to most of the participants being right-handed. In their study of visual attention with a Posner-paradigm, Gissing, Thiel, Stephan, Roesler and Fink (2004) found that reaction times of the left and the right hand varied according to target side. For both hands, reaction times were always shorter for ipsilateral targets. In this study, 16 of the 19 participants whose data were analysed, were right handed. It could be that the faster detection of targets that were presented in the right visual field reflected a faster reaction time for ipsilateral targets with the right hand. Handedness was not included as a factor in data analysis in this study and therefore this postulate cannot be confirmed. Further studies are suggested to include handedness as a factor and to address this issue.

4.2. Event-related potentials

The present study partly replicates the results of previous ERP studies of eye gaze cuing and provides some new information about reflexive attention orienting by biological and symbolic cues. Both eye gaze and arrow cues appeared to trigger reflexive attention orienting, resulting in speeding up and enhancement effects of P1 and N1 components. The results were not fully conclusive but rather electrode-dependent. There were partially distinctive effects depending on the cue type, but these were also not conclusive and were limited to certain electrodes. The latencies of the two components were modulated by laterality of target presentation, generally resulting in faster peaking of the components in the hemisphere that was contralateral to target presentation. Previous studies have found gaze cues to result in shorter latencies of the visual P1 and N1 components (Schuller & Rossion, 2001, 2004). Symbolic cues have normally resulted only in amplitude enhancements (Eimer, 1997; Luck et al., 1994, 2000; Mangun & Hillyard, 1991). In the present results, the component P1 peaked earlier in congruent than in incongruent trials in the right hemisphere (electrodes P6 and P4). There was no clear effect of congruency in the left hemisphere at this point. Congruent trials resulted in faster peaking of the N1 component on electrodes P3 and P4. On electrode P5, the N1 peaked earlier in congruent gaze than in congruent arrow or incongruent gaze trials. On electrodes P6 and P4, congruency interacted with laterality of target presentation. The N1 peaked

earlier in congruent and incongruent trials, where target was presented in the left visual field in comparison to congruent and incongruent trials, where target was presented in the right visual field. According to Corbetta and Schulman (2002), reflexive attention is largely lateralized to the right hemisphere. In Schuller and Rossion's study (2004), attention was speeded up mainly in the right hemisphere. In the present results, visual component P1 seemed to be speeded up by attention in the right hemisphere only, whereas the N1 was speeded up in both hemispheres.

Previous studies of spatial attention have reported amplitude enhancements of the visual components (Eimer, 1994; Luck et al., 1994; Mangun & Hillyard, 1991). Both symbolic (Eimer, 1997; Luck et al., 1994, 2000; Mangun & Hillyard, 1991) and eye gaze cues (Schuller & Rossion, 2001, 2004) have resulted in amplitude enhancements. It has been proposed that these amplitude enhancements of the visual P1 and N1 components result from an attentional sensory gain control mechanism, which modulates information flow in a different way between those parts of the visual field that are being attended and those that are ignored (for a review see Luck et al., 2000). In this study, amplitude enhancements in congruent trials were also observed. In the left hemisphere (electrodes P5 and P3), congruent arrow trials (compared with incongruent arrow and both types of gaze trials) resulted in maximal enhancement of the P1 component. On the electrode P3, incongruent gaze trials resulted in larger P1 components than congruent gaze cues did. In their study with dynamic eye gaze, Schuller and Rossion (2001) observed exactly the same effect on the same electrode. A similar effect has also been reported earlier with arrow cues (Mangun & Hillyard, 1991). It has been interpreted as an enhancement that occurs when target probability decreases. This enhancement indicates that eye gaze is indeed effective in manipulating the participant's expectancy of a target location (Schuller & Rossion, 2001). In the right hemisphere (electrode P4), incongruent trials, where the target was presented in the right visual field, resulted in maximal P1 enhancement. The amplitude enhancements were partially modified by laterality of target presentation; ipsilateral targets seemed to result in maximal enhancements of the P1 component. Previous studies have reported enhancements of the P1 contralaterally (Mangun & Hillyard, 1990) and ipsilaterally (Rugg, Milner, Lines, & Phalp, 1987). The N1 component was enhanced in congruent trials when compared with incongruent trials in the left hemisphere. In the right hemisphere, there was also a tendency ($p = .089$)

for amplitude enhancements of N1. On electrode P6, N1 was larger in congruent than in incongruent trials. On the N1, maximal amplitude enhancements were observed with contralateral targets. The present study thus replicates the earlier observations of amplitude enhancements and shows that amplitude modulations of the early visual components can be observed with both cue types. This indicates that both cue types produce an attentional sensory gain control mechanism, which modulates information flow in a different way in those parts of the visual field where the attention has been directed to than in those parts of the visual field, which are not attended. Both arrows and gaze cues seem to be effective in producing reflexive attention.

Both components P1 and N1 peaked earlier in gaze than in arrow trials. Interestingly, this was in contrast with the behavioural data, where reaction times were shorter in arrow than in gaze trials. In light of these results, it seems that the difference in reaction times results from the phase after the target has been detected and is possibly related to motor execution of a behavioural response. At the moment however, it is difficult to find explanation for this effect.

Previous ERP-studies with gaze direction cues (Schuller & Rossion, 2001, 2004) have used a digitalized photograph of a human face. In the present study, the cue was a schematic face, which also resulted in speeded attention and enhancement effects in congruent trials. Arrows resulted in both speeding up and amplitude enhancement effects of the P1 and N1 components too. Studies have proposed that visual-spatial attention modulates neural activity in the extrastriate cortex, where the neural sources of the P1 and N1 have been located (Clark & Hillyard, 1996; Gomez Gonzales et al., 1994). The present results give further evidence that visual-spatial attention by both eye gaze and arrows modulates neural activity in the extrastriate cortex and that the behavioural advantages observed in reaction times are at least partially caused by enhanced sensory processing. Components peaking earlier after gaze than after arrow cues throughout most of the data indicates that the neural mechanisms of attention orienting by the two cue types, biologically relevant and symbolic, may not be similar. Based on their results, Kingstone et al. (2004) argued that reflexive attention orienting by eye gaze is uniquely subserved by superior temporal sulcus, the neural architecture, which, according to a wealth of research, is responsible for the processing the eyes of others. The different time course of visual components in the

eye gaze and the arrow trials observed in the present study may be an indication of separate underlying neural mechanisms for reflexive attention orienting which appears behaviourally similar. In addition to this however, there were only a few distinctive effects depending on cue type, which indicates that central eye gaze and arrow cues may share at least some similar attentional processing mechanisms and eye gaze may not be as unique in producing reflexive attention as previously thought. However, on the basis of these results only, it is difficult to deduce the neural mechanisms of attention orienting by eye gaze and arrows and further studies are needed. It must also be noted, that the ERP's recorded in this study reflect neural events in the visual areas processing the target. It is possible that the mechanisms of attention orienting behind eye gaze and arrow cuing are different, but the effects of them are the same, or relatively similar in visual areas.

According to the knowledge of the author, this is the first study, which explores neural mechanisms of attention orienting by both eye gaze and arrow cues in the same study. More studies using a similar spatial cuing paradigm are required to further explore these results, which indicate that eye gaze and arrow cues may engage similar attentional mechanisms. Dipole-modelling studies that provide implications about the neural sources of ERP-components are important in order to explore the exact neural mechanisms of attention orienting by gaze and arrow cues. In general, the event-related method may not be the best method for studying the locations of these two types of attention orienting but it can provide detailed information about the time course of attention orienting following these two cue types. For studies that aim to establish the locations of reflexive attention orienting triggered by eye gaze and arrow cues, it is proposed that neuroimaging experiments are conducted.

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