COMPARISONS OF THE NEURAL MECHANISMS OF VOLUNTARY, REFLEXIVE, AND SOCIALLY-DIRECTED ATTENTION

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A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Psychology.

Chapel Hill
2007

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ABSTRACT

VICKI WEST: Comparisons of the Neural Mechanisms of Voluntary, Reflexive, and Socially-Directed Attention
(Under the direction of Joseph B. Hopfinger)

Visual attention serves to select, from amongst a huge influx of visual information, an item or location to receive greater processing. This focus of attention can be directed voluntarily or it can be reflexively captured by a sudden onset or movement. In recent years another type of attentional orienting has been studied: “social gaze orienting”. In this type of orienting, the gaze of another person automatically causes one’s attention to shift in the direction of the gaze. While this attentional shift is automatic in nature, its properties differ from those typically associated with reflexive orienting, especially on terms of the timing of facilitation effects. The relations between social gaze cueing, voluntary cuing, and reflexive cueing are not well understood. The current study explores the similarities and differences between the neural mechanisms of these types of orienting using event-related potentials (ERPs). ERPs allow us to explore differences in the neural underpinnings of voluntary, reflexive, and social gaze orienting that may or may not be exhibited in overt behavior. In Experiment 1, it was discovered that a localization task at cue-target SOAs of 50-250 and 300-500ms was able to produce significant effects on behavior. In Experiment 2, when timing was the same for each type of attention (an SOA of 300-500ms), behavioral and early visual ERP effects were similar for social and voluntary attention, but reflexive attention showed a different pattern. In Experiment 3, when timing is varied for each type of attention, producing the strongest effects on behavior, greater differences between social and voluntary cuing emerged, as social attention no longer showed any significant effects on early visual ERPs. In both ERP experiments social attention showed increased amplitude for invalid targets on late negative component peaking around 420ms after the target. For reflexive and voluntary attention, in both experiments, this effect is either absent or reversed suggesting that continued processing that occurs after target response is distinct for social attention. These new findings suggest that while more similar to voluntary attention, social attention shows distinct processing at some levels, suggesting it should not be considered equivalent to reflexive or voluntary attention.

ACKNOWLEDGEMENTS

I am greatly thankful to my advisor, Dr. Joseph Hopfinger for his help and guidance, not only on this project, but all the others over the past five years as well. I would also like thank the rest of my dissertation committee including, Dr. Mark Hollins, Dr. Kelly Giovanello, Dr. David Penn, and Dr. Marilyn Hartman, who all offer wonderful suggestions for developing and improving the current research. I would like to thank Emily Leonard for creating James, the stimulus for the current studies, as well as Kevin Denny and James Bedford, for helping me to run many ERP subjects. Finally I would like to thank my family for helping me make it through the times over the past five years that I wasn't sure if I would make it, Mom and Dad, Wendi, Dave and Kelsey, and most of all Andrew, Avery and Samantha who put up with many missed dinners and walks and were still always there to calm me down when this project became overwhelming.

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CHAPTER 1

INTRODUCTION

An enormous amount of information is presented to our sensory systems at any given moment. The ability to focus upon a subset of this otherwise overwhelmingly complex environment depends, in part, on mechanisms of attention. These mechanisms of selection are influenced by voluntary, top-down processes as well as involuntary, bottom-up processes (e.g. Cheal & Lyon, 1991; Desimone & Duncan, 1995; Jonides, 1981; Müller and Rabbitt, 1989; Posner & Cohen, 1984). Voluntary orienting allows one to consciously pick a location or an item to receive greater processing; this type of orienting is very flexible but also requires effort and mental resources. Reflexive attention, on the other hand, occurs effortlessly with a flash, sudden movement, or other salient event grabbing attention automatically. These types of attentional orienting serve to provide greater processing of the attended stimulus in a given modality. For the current study, the modality of primary interest is vision. When a location or item is visually attended to, it receives greater processing within multiple visual processing cortical regions. This is evident as increased attention to a particular stimulus leads to greater activation in visual areas in functional Magnetic Resonance Imaging (fMRI) studies (e.g. Hopfinger et al., 2000; Kasnter et al., 1999; Liu et al., 2005), greater amplitude in neural responses measured at occipito-parietal scalp locations by event-related potentials (ERPs) (e.g. Van Voorhis & Hillyard, 1977; Mangun and Hillyard, 1991; Mangun et al, 2000; Hopfinger & Mangun, 1998;2001), and greater accuracy and faster reaction times to the attended versus unattended stimulus (e.g. Posner, 1984). Other modalities (e.g., touch, audition) show similar enhancements in processing (Tracey et al, 2002; Petkov et al., 2004), although the current study will focus on visual attention.

In recent years, another type of visual attention, social gaze orienting, has been explored (Friesen & Kingstone, 1998; Driver, 1999). Social gaze orienting occurs when one orients attention to a location being overtly attended to, or looked at, by another person. Experimentally, it is generally explored with a photograph or drawing of a face, which moves its eyes to either the left or right before a target appears on either the same side, or the opposite side of the gaze. When the target appears on the same side as the gaze, participants are generally faster and/or more accurate at detection, discrimination, and localization tasks than when the target appears on the opposite side (e.g. Driver et al., 1999; Friesen & Kingstone, 1998). The effect has even been found when rhesus monkeys are viewing gaze cues from another monkey (Deaner & Platt, 2003). Interestingly, this effect seems automatic, but it also seems to differ from reflexive attention in terms of timing as will be described in more detail below. The current study explores voluntary orienting, reflexive orienting, and social gaze orienting and seeks to provide a better understanding of the similarities and differences in these types of orienting.

Specifically, ERPs were used to explore the neural response to target processing following each type of cue. While behavioral measures can provide a good understanding of overt differences, ERPs can provide us with information on differences at the neural level which may or may not exhibit themselves in specific behavioral measures (e.g. Handy et al., 2001). This is important as the simple behavioral studies that are often designed to study attention may not be able to pick up subtle differences that could affect the complex behaviors in which attention is engaged in the real-world.

Three Distinct Mechanisms of Attentional Orienting

Voluntary Orienting

Voluntary attention refers to when one purposefully selects a space or object to which to attend. This is a top-down process of effortfully selecting a location to which to attend. Experimentally, voluntary attention is often produced with the occurrence of a central symbolic cue, indicating which target location a participant should attend to. For example, the letters R and L appearing at fixation could serve as a voluntary cue instructing the participants to attend to the right or left target location, respectively. Usually, the target will be either predictive or instructive in order to encourage the participants to utilize the cue and shift their attention to the valid location. In the case of a predictive cue, the target would occur at the valid location on the majority of the trials (usually between 70% and 80% of the time) (e.g. Posner et al., 1978). In the case of an instructive cue, participants are told to respond only to targets that occur at the valid location and to ignore those that occur at the invalid location (e.g. Clark and Hillyard, 1996; DiRusso et al., 2003; Hopfinger and West, 2006). When participants orient attention in response to a voluntary cue, there is facilitation in the processing of a target that subsequently appears at the valid location making participants' responses to these targets more accurate and/or faster than the invalid location. In voluntary cueing paradigms the cue-target stimulus onset asynchrony (SOA; the timing from the onset of one stimulus to the onset of the next) is usually greater than 300 or 400ms in order to allow participants enough time to shift attention. The facilitation can last a very long time (e.g. 2000ms) as long as the participant has motivation to keep attention engaged at the valid location (e.g. Posner et al., 1980; Müller and Rabbitt, 1989). In a 1980 study, Posner and colleagues not only compared valid and invalid trials, but they also compared both types to neutral trials, in which no information was provided about where the target was likely to occur. They found that responses to valid trials were faster than those to neutral trials, which suggest a benefit of attending to the target location ahead of time. Responses to invalid trials, on the other hand were slower than those to neutral trials, suggesting an extra cost of attending to the incorrect target location, above and beyond the deficits of attending to a neutral stimulus.

Reflexive Orienting

While voluntary orienting requires purposefully directing one's attention, reflexive attentional capture is automatically triggered by external events (e.g. Yantis and Jonides, 1984; Jonides, 1981). A sudden flash or movement may reflexively capture your attention to a particular location. This is an example of a bottom-up process of attentional capture triggered by basic sensory processes. Experimentally, reflexive attention is often produced with a periphera1, sudden onset or offset at a target location. In most reflexive cueing paradigms, the cue is non-predictive and the participants are instructed to ignore the cue in order to ensure that the cue is creating an automatic capture of attention. The timing of reflexive attentional capture greatly differs from that of voluntary attention. At short cue-target SOAs, up to about 300ms, the reflexively valid location shows similar target facilitation to that which is produced in voluntary cueing paradigms. That is, targets at the valid location produce faster and more accurate responses than targets appearing at the invalid location. However, after about 300ms the pattern is drastically different and the invalid targets are actually responded to more quickly and accurately, a phenomenon called inhibition of return (IOR) (Posner & Cohen, 1984).

Differences between Voluntary and Reflexive Attention

Studies have long pointed to a myriad of behavioral differences between voluntary and reflexive attention including, as mentioned above, timing differences. Reflexive attention produces its maximum facilitory effects at short cue to target SOAs up to about 300ms. Around this time IOR occurs and the target processing at the valid location is actually diminished while target processing at the opposite location is facilitated (Posner & Cohen, 1984). Interestingly, it is at these longer cue-target SOAs in which voluntary attention asserts it greatest facilitation effects at the valid target location (e.g. Posner et al., 1980; Müller and Rabbitt, 1989). As well as timing differences, the functional roles that reflexive and voluntary attention play in basic perception have been found to differ. For instance, reflexive attention seems to play a role in the binding of conjunctions of features in object recogntion, while there is no evidence that this occurs with voluntary attentional orienting (Briand and Klein, 1987; Briand, 1998).

ERP and fMRI evidence has suggested the possibility that voluntary and reflexive attention arise from two separable attention systems (e.g. Mayer et al., 2004; Mort et al., 2003; Hopfinger and West, 2006). FMRI studies suggest that when using times in which reflexive and voluntary attention normally exert their greatest facilitory effects they employ different brain areas in covert orienting tasks (Mayer et al., 2004) and overt saccade tasks (Mort et al., 2003). In a recent ERP study, Hopfinger and West (2006) looked at reflexive and voluntary cues occurring within the same trial and found that voluntary and reflexive attention were asserting opposite effects on neural processing at overlapping times during early extrastriate processing of target stimuli following the two types of cues. The evidence suggesting that reflexive and voluntary orienting are two separate attentional systems raises the question of where social gaze orienting may fit into these systems. It seems possible that social attention could be similar to voluntary orienting as it involves the use of a central symbolic cue, but it also seems to be an automatic process, like reflexive orienting, that does not involve effortful orienting.

Social Gaze Orienting

The relationship between the direction of a faces' eye gaze and the viewer's spatial attention has been extensively studied in recent years beginning with simple experiments using line drawings of faces. Friesen and Kingstone (1998) found that non-predictive gaze cues produced automatic attentional orienting toward the gazed at location for detection, localization, and identification tasks even though the participants in the study were informed that the gaze was not predictive of where the target would occur. In a similar study, Driver and colleagues (1999) used pictures of real faces, and explicitly told participants to try to ignore the faces. They found that targets in the gazed at location were automatically attended and responded to faster, even when the participants knew that the gaze direction was counter-predictive (80% of the time the target appeared in the opposite location of the gaze).

In a 2006 study, Bayliss and Tipper found that even in the strongest case, where gaze cues for some specific faces were 100% counter-predictive, participants still followed the gaze of a face on the screen. Throughout the experiment, half of the faces were always non-predictive (the target would appear at the gazed at location 50% of the time), one quarter of the faces were 100% predictive (the target would always appear at the gazed at location), and one quarter were 100% counter-predictive (the target would always appear in the opposite location of the gaze). Forty different faces were used over 480 different trials within the experiment. The authors found that whether participants were completing a categorization task or a localization task, and whether a particular face was predictive, non-predictive, or counter-predictive, the standard gaze-cueing effect was produced, in which there were fewer errors and faster reaction times when the target appeared at the gazed at location compared to the invalid location. Interestingly, at the end of the experiment, participants tended to choose the predictive faces as “more-trustworthy” suggesting that at some level, they were able to pick up on the different contingencies, but still were unable to ignore the gaze direction of “untrustworthy” faces.

Due to its automatic nature, gaze cue orienting is often thought to be similar to reflexive orienting, although evidence suggests that it differs from the classic idea of reflexive orienting. For example, patients with frontal-lobe damage are able to orient attention normally to reflexive peripheral cues, but have problems using central symbolic cues such as words, and also show deficits in orienting to gaze cues (Vecera & Rizzo, 2006). Friesen and Kingstone (2003) directly compared reflexive orienting from a typical peripheral onset cue and orienting produced by a gaze cue by combining both types of cue into a single trial. The fixation display consisted of one circle in each of the four visual quadrants of the screen. The cue was the abrupt onset of a set of eyes (gazing at one of the other circles or straight ahead), a nose, and a mouth. This abrupt onset, gaze cue was followed by the target event (the offset of one of the circles) at the location of the gaze direction, the location of the abrupt onset, or one of the invalid locations. By having simultaneous reflexive and social gaze cues, the authors showed that these two types of attentional orienting produced opposite effects at the same SOA. At the longer SOAs where the abrupt onsets produced IOR, the gaze cue still produced facilitation for the gazed at location. This study also provides evidence that gaze cues do not produce IOR, and continue to produce facilitation for a longer time than peripheral abrupt onset cues, with SOAs as long as 1005ms.

Because gaze cues are central and symbolic they resemble voluntary cues also. In a more recent study, Friesen, Ristic, and Kingstone (2004) looked at the effects of competing gaze cues and top-down voluntary orienting by explaining to participants that gaze cues were counter-predictive. Therefore, the gaze cue would be directing participants' attention in one direction and their volitional control would be directing them in the opposite direction. There were four possible target locations which meant in each trial the target could appear at the gaze cued location, the predicted location (opposite the gaze cue), or one of the neutral locations. The authors found that processing of targets that appeared at both the valid location and the predicted location was enhanced. Interestingly, the faster reaction times for the social gaze cued targets occurred when the cue-target SOA was 105ms or 600ms, but disappeared at an SOA of 1200ms. For the predicted targets, the facilitated reaction times began for SOAs of 600ms and were present for the 1200ms and 1800ms SOAs as well. It is especially interesting that at the 600ms SOA, both the social gaze cue and the predictive, voluntary orienting were producing facilitory effects on target processing in opposite directions. This provides evidence of separable independent systems controlling social gaze orienting and voluntary orienting.

A 2005 study by Friesen, Moore, & Kingstone tested whether the robust gaze cueing effect is due to gaze direction triggering an automatic attention shift, or whether it is simply the abrupt onset of the target triggering the shift, with this shift simply being modulated by the congruency with the gaze direction. They found that the gaze cueing effect for a single lateralized sudden onset target was the same as that for a lateralized peripheral onset that occurred simultaneously with another peripheral onset at the opposite target location, suggesting that the gaze cue, and not the sudden onset, produced an automatic attention shift.

In a paradigm similar to those presented above, Langton and Bruce (1999) looked at another type of joint social attention cue. Rather than the centrally presented face moving its gaze, the entire head would turn in one of four directions: up, down, left or right. Both predictive and non-predictive cues produced an effect very similar to the gaze cueing effect reported above, where responses were faster for targets that appeared at the valid locations, but this effect was only found with a 100ms cue-target SOA and was absent at longer SOAs (500ms and 1000ms). The effect also disappeared when the face was turned upside down suggesting that the effect of the cue is related to the social nature of the complete face and not just the movement of the eyes.

Gaze cues have also been found to interact with other types of social variables such as facial expression. While some studies find no evidence of an interaction between facial expression and gaze cueing (Hietanen & Leppänen, 2003), many show that under certain circumstances, an interaction is present. For example, a recent study (Tipples, 2006) compared happy, fearful, and neutral faces and found that while the cueing effect for happy faces did not differ from that for neutral faces, the fearful faces produced a greater cueing effect than the neutral faces. However, in a 2005 study, Hori and colleagues compared happy and angry faces to neutral faces of males and females and found that happy faces did produce faster responses to targets that were congruent with gaze, but only for female faces. There were no other interactions between sex, facial expression, and gaze cue. Another study points to possible reasons why some studies do not find interactions between facial expression and gaze cue. Similar to the findings of Tipples (2006), Mathews and colleagues (2003) found that fearful faces could lead to an increased gaze cueing effect. In this study though, high anxiety participants and non-anxious participants were studied separately, and only the high anxiety participants showed this increased cueing effect for fearful faces. These interactions between facial expression and attentional cueing offer more evidence that the gaze cueing effect has a distinctly social component and that it is not simply a sub-type of the classically defined reflexive or voluntary attention.

A study by Ristic, Friesen, & Kingstone (2002) also pointed to the social component of the gaze cueing effect by comparing the effects of the non-predictive eye gaze cues, to non-predictive central arrows, which also produce automatic orienting. The arrows and gaze cues produced very similar effects in both adults and in preschool aged children, but interesting differences were observed in split-brain patients who showed reflexive orienting to non-predictive arrows in both visual fields. A previous study of two split brain patients who show face processing advantages in opposite hemispheres suggested that gaze cues only produce reflexive orienting when the gaze cue projects to the hemisphere specialized for face processing (Kingstone, Friesen, and Gazzaniga, 2000). This subtle difference suggests that there is something special about social gaze orienting.

Behavioral measures of accuracy and response times have been able to provide a basic platform of information on how all three types of attention discussed here (voluntary orienting, reflexive orienting, and social gaze orienting) operate. Specifically, behavioral evidence has suggested that, at certain cue-target SOAs, all three types of orienting lead to increased accuracy and faster reaction times at the valid location, suggesting greater visual processing of the target stimulus. However, it is important to point out that overt behavioral measures do not always provide a complete understanding of how perception is being enhanced (e.g Handy et al., 2001). Therefore, it is necessary to explore perceptual enhancement with the use of ERPs. ERPs provide a greater understanding of these attentional mechanisms, as they can provide us with information on the timing of the underlying neural processes that give rise to the overt behavioral effects. They allow us the opportunity to explore the rapidly occurring differences in neural processing taking place in a matter of milliseconds. Therefore, while the currently employed behavioral measures show similar overt validity effects, the underlying neural mechanisms may be different. Again, behavioral studies are carefully controlled and are designed to explore specific properties of perception and performance (usually accuracy and reaction time) and may not be able to pick up subtle effects on performance that could be represented in ERP waveforms. ERPs of voluntary and reflexive attention have been studied extensively, while less information is available on the underlying neural mechanisms of target processing following a social gaze cue.

Event-Related Potentials of Attentional Orienting

Behavioral facilitation can be produced by a number of different types of neural responses. Faster reaction times could be due, for example, to an increase in the strength of the signal measured by ERPs, or to faster latencies of the processing response. Also, the underlying activity could be produced in a number of different areas, exhibiting themselves in the topography of the ERPs. Therefore, ERPs can allow us to find distinct differences between the different types of attentional orienting in addition to, and even in the absence of, obvious behavioral differences.

Voluntary Orienting

Voluntary attention effects on visual evoked potentials have been found to be fairly consistent over many years. The earliest visual ERP component, the striate generated C1 or NP80 component, has not been found to be affected by voluntary attention (e.g. Martinez et al., 1999; Di Russo et al., 2003). The NP80 occurs at about 50-60ms after the onset of the target and can be seen as a negative or positive peak in the waveform depending on where in the visual field the target stimulus appears (e.g. DiRusso et al, 2003). This component is not even affected in possibly the strongest case of attentional modulation when both a voluntary cue and reflexive cue direct attention to the same target location (Hopfinger & West, 2006).

The later, extrastriate generated, P1 component however, has been shown to be significantly enhanced by voluntary attention (e.g. Eason et al., 1969; VanVoorhis & Hillyard, 1977). The increase in amplitude is often evoked using a task that involves the detection of infrequent peripheral targets amongst frequent ones (e.g. Clark & Hillyard, 1996; DiRusso et al., 2003; Heinze et al., 1994; Mangun and Hillyard, 1991; Martinez et al., 1999). In these studies, attention is usually directed by instructing the participant to pay attention to either the left or right visual field at the beginning of a block, or with an arrow pointing to possible target locations throughout the block. In a 1997 study, Mangun and colleagues found that the difficulty of the task can affect the size of the P1 attention effect. A difficult task, requiring subjects to decide if two symbols on one side of the visual field matched one another, produced a greater attention effect at the timing of the P1 component.

This was in comparison to a simpler task involving the detection of a dot that appears amongst the symbols. It is important to note, however, that the dot (simple detection) task still produced a significant amplitude increase at the timing of the P1 component for valid trials compared to invalid trials, but the effect was larger for the more difficult task. Handy and Mangun (2000) also found that manipulation of the task can affect the amplitude of the P1 component. The authors looked at the effects of varying levels of perceptual load. The discrimination of the targets in the low load was a fairly easy discrimination, where as in the high perceptual load, the possible targets were more similar and harder to distinguish from each other. The authors found that the high perceptual load conditions can produce a greater P1 attention effect.

The amplitude of the extrastriate generated N1 component has similarly been found to be enhanced with voluntary attention, and some studies also suggest that this N1 amplitude effect may depend on task and stimuli parameters (Handy & Mangun, 2000; Vogel & Luck, 2000). As well as finding an effect of perceptual load on P1 amplitude, Handy and Mangun (2000) found that the visually evoked N1 component in this experiment only showed significant attentional enhancement in the high visual load task. Rather than increasing the perceptual load, Vogel and Luck (2000) looked at the effects of changing the task that participants completed. Rather than comparing the attention effects on the N1 component, they simply compared the amplitude of the N1 component for central targets that required a discrimination judgment to those that simply required detection. They found that the N1 component had greater amplitude for targets that required discrimination than those in the simple detection task.

The main voluntary attention effects that are observed in the early visually evoked ERPs to target stimuli are seen in the modulation of the amplitude of the early P1 and N1 components. These differences can vary by hemisphere of the brain, and specifically are usually stronger and occur earlier in the hemisphere contralateral to where the target is appearing as this hemisphere's striate and extrastriate cortex first process the incoming visual information. While behaviorally, faster reaction times are often observed for valid trials compared to invalid trials, latency differences in the early components of the visual ERPs are not typically observed with voluntary attention tasks.

Later latency components have also exhibited amplitude increases in the absence of latency differences for increased attentional allocation. For example, Mangun and Hillyard (1990) found that the amplitude of the P300 (occurring 400-800ms after the onset of the target stimulus) component increased when attention was 100% focused on the target location compared to when it was divided 50/50 between the two target locations. In this case, the amplitude was greater than when attention was 100% at the opposite target location. The P300 component indexes higher order cognitive processing such as human information processing. It is specifically related to the perceived relevance of a stimulus, and is also involved in context updating (Donchin, 1981; Duncan-Johnson & Donchin, 1982). This suggests that participants may perceive voluntarily valid items as being more important and relevant. Another line of research suggests that the P300 ERP component is also a marker of attentional orienting in response to an odd, novel, or infrequent stimulus (e.g., Ritter, Vaughn, & Costa, 1968; Roth, 1973, Squires, Squires, and Hillyard, 1975). In a typical oddball task, an infrequent target is interspersed with frequent distracters and participants are required to respond to the odd target. A three-stimulus paradigm, in which a novel stimulus is present in addition to the frequent distracters and infrequent targets, suggests there are two different distributions of the P300 component. The P3b component has central parietal distribution and is elicited in the three-stimulus paradigm to the infrequent target stimuli. The P3a, which has a more anterior distribution is elicited by novel stimuli, such as a dog bark presented in a pitch discrimination task (e.g. Courchesne et al., 1984; Knight, 1984).

Reflexive Orienting

Visually evoked ERPs of target processing following reflexive attentional cues have similarly been found to produce amplitude differences in some components, while latency differences are, again, typically absent. Hopfinger and Mangun (1998; 2001) found evidence that exogenous attention produces modulations in one early sensory component similar to the modulations produced by voluntary attention. With both high load (target discrimination) and low load (simple detection) tasks, the authors found that the level of processing indexed by the P1 was the first level of processing to be affected by a peripheral abrupt onset. At short SOAs (34-234ms), where one would expect facilitation of target processing in behavior, the P1 amplitude was enhanced, while at longer SOAs (566-766ms), during the time range in which one would expect IOR in behavior, the P1 was not enhanced (also replicated in McDonald et al., 1999; Prime and Ward, 2004). In fact, when participants were completing a discrimination task, the P1 at long SOAs was significantly reduced for valid targets compared to invalid targets (Hopfinger and Mangun, 1998).

Unlike with voluntary attention, the level of processing indexed by the N1 component was not enhanced even in the discrimination task. Some studies, in fact report a reduction in the N1 amplitude at valid target locations (e.g. Fu et al., 2001), but other studies suggest that the cueing effect on the P1 is simply extended over a longer period of time, pulling the N1 at valid locations more positive, rather than the invalid location being enhanced (e.g. McDonald et al., 1999; Hopfinger and Ries, 2005).

Later latency components such as the P300 have been explored in reflexive attention paradigms as well. Again, the P300 component indexes later stages of information processing such as the perceived relevance of a visual stimulus. Similar to voluntary attentional modulation, reflexive cueing of a visual target has been found to lead to an increase in P300 amplitude when SOAs are short enough to produce facilitation. This suggests that the reflexive cue leads subsequent valid targets to be considered more relevant to the task (e.g. Hopfinger & Mangun, 1998; 2001).

Social Gaze Orienting

A few recent studies have used ERPs to explore the role of gaze cues on subsequent target processing. As this is the least explored of the types of orienting, the three studies that exist will be more thoroughly discussed than those exploring voluntary and reflexive attention. Schuller and Rossion (2001) used a non-predictive gaze cue and replicated the behavioral finding that participants were faster at responding to the location of a target that appeared in the gazed at location as compared to the opposite location. The ERPs to these targets suggested this social cue is able to affect neuronal processing of the visual target at the stage of processing indexed by the P1 and N1 components. Specifically, a latency shift and an amplitude increase were observed in both of these components, where valid targets produced earlier and larger components compared to invalid targets. The latency differences are especially interesting as most experiments using reflexive peripheral cues or symbolic central cues primarily find amplitude differences, but rarely find latency differences. While no latency difference was reported for the P300, the author did report increased amplitude of this component for invalid trials. This is at odds with voluntary and reflexive paradigms that have produced increased P300 amplitude for valid trials, but the authors did not discuss this finding.

In a following study, Schuller and Rossion (2004) addressed a shortcoming of their original study. In their first study, each trial began with the face stimulus looking straight ahead, after which the eyes moved either towards the left or the right, thus possibly producing a confounding movement cue as well as a social gaze cue. The movement in one direction or the other could produce a typical reflexive cue for the target location in the direction of the eye movement. In the 2004 study, they used a similar paradigm but in this case the eyes would be directed to either the left or the right when the face appeared at the beginning of the trial (to eliminate the movement cue). Then, after a 500ms SOA, the target appeared in a location either congruent or incongruent with the gaze direction. This study also included the addition of neutral trials in which the gaze was straight ahead throughout the trial. The previous study found that when the target was valid it produced increased amplitude and shorter latency for both the P1 and N1 components compared to when the gaze was in the opposite direction of the target. This allows for the possibility that visual processing of the cue targets is enhanced and speeded or that the processing of the invalid targets is diminished and slowed. The addition of neutral cues allows the authors to explore whether this social gaze cue produces a benefit for valid stimuli and/or a cost for invalid stimuli. The behavioral findings for this study suggest that the cue produces a benefit for the valid location, but not a cost for the invalid location as reaction times to valid targets were significantly faster than those to neutral or invalid targets, but there was no significant difference between reaction times for neutral and invalid targets. The latency of the extrastriate P1 component showed a similar pattern to the reaction times, as the valid target produced a P1 with a significantly earlier peak than the neutral or the invalid targets. There was no significant difference in latency between the neutral and invalid targets. While there was no significant main effect of validity on amplitude of the P1 component, there was an interaction between congruency and hemisphere, where the right hemisphere exhibited a significantly larger P1 for valid targets compared to neutral and invalid targets; there was no difference in amplitude for the neutral and invalid trials. The left hemisphere showed no significant amplitude difference due to congruency.

The N1 component showed similar modulation by the gaze cue. The N1 peak occurred significantly sooner for valid targets as compared to neutral or invalid targets (with no significant difference in latency for neutral compared to invalid targets). However, when accounting for the P1 latency differences, there was no significant additional speeding of the target processing for valid targets. The main effect of congruency on amplitude on the N1 component approached significance (p=0.069) with the valid targets producing a larger N1 component than neutral and invalid targets. Similar to the P1 component, there was an interaction between hemisphere and congruency where the valid targets produced a significantly greater amplitude N1 component than the neutral or invalid trials in the right-hemisphere; again there was no significant difference between neutral and invalid targets and there was not a significant congruency effect in the left hemisphere. The results of this study suggest that even without the movement cue produced by the eyes shifting, there are differences in amplitude and latency of the P1 and N1 components for targets that are preceded by a congruent eye gaze cue compared to those that are not. The addition of a neutral condition allowed the authors to conclude that the gaze cue produced an enhancement and speeding of processing for valid targets and not an inhibition in processing invalid targets.

The same group again found similar results in a more recent study (Schuller and Rossion, 2005). In this study, instead of the asterisk used in the previous studies, the target consisted of a checkerboard pattern stimulus. This larger stimulus is able to produce a larger neural response. While the SOA in the previous experiments (Schuller and Rossion, 2001; 2004) remained constant at 500ms, it varied between 500 and 700 ms in this study. The other main difference in this study was that rather than appearing just to the left and right of the face, targets in this study could appear in each of the four quadrants of the screen (upper left, upper right, lower left, lower right). This manipulation allowed the authors to explore processing indexed by the C1 ERP component which can be a positive wave or a negative wave depending on the visual field in which it is presented. The authors found no evidence of a gaze cueing effect during the timing of the C1 component, but did find similar P1 and N1 effects as in their previous studies. They found that targets congruent with gaze direction produced earlier and larger P1 and N1 components.

Each of the three types of attentional orienting explored here (voluntary, reflexive, and social gaze orienting) seem to lead to facilitation of processing at the valid locations, as indexed by both behavior (reaction times and/or accuracy measures) and by ERPs. While voluntary and reflexive orienting have been studied for many years, the exploration into the cueing effects produced by social gaze cues is comparatively new. The behavioral evidence that suggests IOR does not occur in social gaze orienting suggests that it is a different process than what occurs in peripheral reflexive orienting. While these few ERP studies of social gaze orienting seem to suggest that the underlying neural signature of this social orienting is different from both reflexive and voluntary orienting, no studies directly compared these three specific types of attention in a within-subject design. Also, no studies with which I am familiar has explored voluntary or reflexive attention at the timing used in these ERP studies exploring social gaze orienting. It is also important to point out that all three experiments exploring the ERPs of social gaze orienting use a localization task in which participants are required to respond to the location of a lateralized target. Again, no studies, to my knowledge, have used this type of task in a voluntary or reflexive cueing paradigm. The ERP studies of social attention show latency differences in early visual processing components, but it is unclear if these difference are related to the use of a social attention cue, or if they are due to varying stimuli, tasks, and timing. By using the same subjects, the same timing, and the same task with social gaze orienting, voluntary orienting, and reflexive orienting, strict controls are provided and the neural responses underlying target processing can be compared.

Current Study

The current set of experiments explores the similarities and differences between voluntary, reflexive, and social gaze orienting in typical young adults. Previously, social gaze orienting has been shown to be an automatic process as it occurs even in situations where it is not beneficial, and in some cases even harmful for performance to follow the gaze of a face. However, behavioral differences between reflexive and social gaze orienting have been found. Specifically, some studies suggest that gaze cues, unlike reflexive cues, do not produce IOR (Friesen & Kingstone, 2003), and in fact, produce facilitation at the valid location long after reflexive attention effects typically disappear. Therefore, it is unclear what similarities and differences exist between social gaze orienting, reflexive orienting, and voluntary orienting.

Previous studies have used ERPs to look at the neural processing of targets following social gaze cues (Schuller & Rossion, 2001; 2004), but to our knowledge, none have directly compared the three types of attention using similar targets, attempting to control for timing differences, or in within-subjects design. Also, all of the ERP studies looking at social gaze cueing have used a task (localization) that has not been explored using voluntary or reflexive orienting. This study is specifically designed to look at ERP responses to the same target stimuli over three different types of attention cue: (1) a voluntary, central symbolic cue, (2) a reflexive peripheral flash, and (3) a social gaze cue. This design allows for the exploration of how these types of cues affect targets processing differently, as opposed to only providing information on how the valid trials compare to invalid trials for each of the cues separately. Using ERPs as well as collecting behavioral responses allows us to explore how difference in behavior may be related to specific differences in amplitude and latency of components in the ERP waveform. Exploring amplitude, latency, and topographic (where on the scalp the components are localized) differences in ERP components between the three types of attentional orienting provides a greater understanding of why subtle behavioral differences are often seen

CHAPTER 2

EXPERIMENT 1A: PILOT STUDY; SOCIAL DISCRIMINATION

Experiment 1a explored the behavioral cueing effect of our social gaze stimuli and explored the effects of different SOAs on accuracy and reaction time with the current stimuli. This was done so I could be confident that the cueing effects found previously can be reproduced. Most of the gaze cue studies discussed above have used actual photographs of faces as cues. For the current study, a realistic face with straight and diverted gaze was created using POSER software (Version 6; by e-frontier/Curious Labs, Scotts Valley, CA). The stimuli were created with this software to allow complete control over symmetry in lighting, facial features, and background conditions which are hard to control for in photographs of real faces. Because responses to targets appearing laterally are measured, it is important that there are no physical differences between the left and right side of the cue stimulus that may lead to participants favoring one side over the other. Creating gaze stimuli also allows for the creation of more realistic scenarios than are often used in gaze cueing experiments. In most gaze cueing experiments, a diverted gaze is followed by a peripheral target appearing in mid air on either side of the face. We were able to make the target appear more realistic by adding cylinders that act as place holders out of which the targets appear to pop.

This experiment served as a pilot study to ensure that the behavioral effects found with photographs of faces can be replicated using our created face. Also, a wide range of SOAs has previously been found to produce facilitory cueing effects, so this experiment explores the behavioral effects produced with the gaze cues at the timing normally associated with robust reflexive cueing effects, the longer SOAs associated with robust voluntary cueing effects, and a middle range SOA which has previously been found to produce robust social gaze cueing effects. This will provide an understanding of what timing best produces the facilitory effects of the gaze cue on target processing with the current stimuli.

For the ERP study, a difficult discrimination task was preferred to delay the response in the ERPs due to motor preparation. Most previous studies exploring social gaze orienting, however, use either detection or localization tasks.

Methods

Participants

Participants consisted of 13 undergraduate students (all females) with a mean age of 18.5 years old (range-18-19). All participants had 20/20 or corrected to 20/20 vision, determined by self report. Participants were recruited through the participant pool of the University of North Carolina at Chapel Hill. In return for their participation, they received credit towards the completion of their General Psychology class.

Materials and Procedure

Throughout the experiment, a male face constructed with POSER software was presented centrally on the screen. A target consisting of either a blue or purple ball occurred on either side of the face. A trial began with the face moving its eyes towards either a left or right peripheral location. After a variable cue-target SOA, the target appeared to either the left or the right side of the face for 100ms. The eyes return to the center of the screen after 600ms, and a new trial began after a variable inter-trial interval (ITI). (See Figure 2 for and example of the events in one trial). The target was non-predictive and was just as likely to occur in the valid location (the direction in which the eyes look) as the invalid location. Short (50-250ms), mid-length (300-500ms), and long (600-800ms) SOAs were each run in separate blocks. As well as varying between blocks, the SOAs in each block varied within the block (with a 200ms range). This timing was specifically being explored for a later ERP study. During the ERP study, the SOAs for each condition need to be jittered, or variable, in order to complete the adjacent response (Adjar) technique which has previously been used to remove overlapping activity of the cue and target. This is necessary due to their close temporal proximity (Woldorff, 1993; Hopfinger & West, 2006). The ITIs were 1200-1700ms in the long SOA blocks, 1500-1700 for the middle SOA blocks, and 1750-2250 for the short SOA blocks, in order for the total average trial length to be the same in each type of block. Participants were instructed to respond with one button if the ball was blue and another if it was purple. Each block consisted of thirty two trials total, 8 each of right valid, right invalid, left valid, and left invalid. The experiment lasted a total of about one hour and consisted of a total of 12 blocks, 4 blocks for each of the 3 different SOAs.

Data Analysis

Accuracy and reaction times for correct responses were averaged for each block and six 2 x 2 ANOVAs (one each for accuracy and reaction time in each of the SOAs: short, mid-length and long) with factors of validity and visual field were conducted.

Results

For the fastest SOA (50-240ms) there were no significant effects of validity or visual field for reaction time measures (validity: $F_{(1, 12)}$=0.77, p=0.40; visual field: $F_{(1, 12)}$=0.22,

p=0.65; interaction: $F_{(1, 12)}$=0.00, p=0.97). For the middle range SOA (300-500ms) there was again no main effect of validity ($F_{(1, 12)}$= 1.01, p=0.33) and no significant interaction between validity and visual field ($F_{(1, 12)}$=0.05, p=0.82). There was a significant effect of visual field ($F_{(1, 12)}$=5.56, p=0.04) with right targets evoking a faster response than left targets (Right=620.9ms, Left=641.8ms). For the longest SOA (600-800ms) there was no main effect of validity or visual field and no significant interaction (validity: $F_{(1, 12)}$=0.58, p=0.46; visual field: $F_{(1, 12)}$=0.14, p=0.71; interaction: $F_{(1, 12)}$=0.01, p=0.91). (See Table 1 for a complete list of the means).

Similarly, accuracy measures showed no significant effects at short SOAs (validity: $F_{(1, 12)}$=0.03; p=0.87; visual field: $F_{(1, 12)}$=0.63, p=0.44; interaction $F_{(1, 12)}$=1.25, p=0.29), middle range SOAs (validity: $F_{(1, 12)}$= 0.21, p=0.65; visual field: $F_{(1, 12)}$=0.05, p=0.82; interaction: $F_{(1, 12)}$=0.97, p=0.34), or long SOAs (validity: $F_{(1, 12)}$=0.70, p=0.42; visual field: $F_{(1, 12)}$=3.026, p=0.12; interaction: $F_{(1, 12)}$=0.25, p=0.62). (See Table 2 for a complete list of the means.)

Discussion

The results of Experiment 1a suggest that no gaze cuing effects were produced with the current task and stimuli as there were no significant validity effects in either reaction time or accuracy measures for any of the three SOAs. While early social gaze studies report that gaze cues show a validity effect for detection, discrimination, and localization tasks (e.g. Friesen and Kingstone, 1998), many studies use only a localization task (e.g. Schuller and Rossion, 2001, 2004, 2005; Hori et al., 2005). This brings up the possibility that the cuing effects are more robust with localization tasks, and that the effects may be harder to elucidate with a discrimination task. Because the stimuli used in the current task were unable to elucidate the cuing effects with a discrimination task, a second pilot study was conducted using similar stimuli, but with a localization task.

CHAPTER 3

EXPERIMENT 1B: PILOT STUDY; SOCIAL LOCALIZATION

Since the original pilot study did not produce significant cuing effects at any SOA, a second pilot study was completed in an attempt to find a task that did produce a significant behavioral effect for the ERP studies proposed here. In this study, the participants' task was changed from a blue/purple discrimination task to a localization task in which the participants are required to specify with a button press whether the target appeared on the left or right side of the face. This was changed from the original pilot study because a localization task is often used in the literature.

Methods

Participants

Participants consisted of 12 undergraduate students (8 females) with a mean age of 18.8 years old (range:18-21). All participants had 20/20 or corrected to 20/20 vision, determined by self report. Participants were recruited through the participant pool of the University of North Carolina at Chapel Hill. In return for their participation, they received credit towards the completion of their General Psychology class.

Materials and Procedure

Materials and procedures were identical to Experiment 1a, except instead of the targets being blue 50% of the time and purple 50% of the time, the targets were always blue. Also, rather than making a color discrimination of the targets, participants were now instructed to make a localization judgment in which they were required to press one button if the target appeared on the right side of the face and another if it appeared on the left.

Data Analysis

Data Analysis was identical to Experiment 1a.

Results

For the fastest SOA (50-240ms) there was a significant validity effect for reaction time ($F_{(1, 11)}$=46.07, p<0.001). There was no visual field effect ($F_{(1, 11)}$=0.11, p=0.74) or interaction between validity and visual field ($F_{(1, 11)}$=0.10, p=0.76). Reaction time measures for the middle range SOA (300-500ms) showed a significant main effect of validity ($F_{(1, 11)}$=22.43, p=0.001). There was no visual field effect ($F_{(1, 11)}$=0.12, p=0.73) but there was a significant interaction between validity and visual field ($F_{(1, 11)}$=5.44, p=0.04). This interaction suggests that there is a larger validity effect in the left visual field (31.1ms) than in the right visual field (18.0ms). For the longest SOA (600-800ms) there was no main effect of validity for reaction times ($F_{(1, 11)}$=2.64, p=0.13). There is also no visual field effect ($F_{(1, 11)}$=0.03, p=0.87) or interaction between validity and visual field ($F_{(1, 11)}$=0.30, p=0.59). See Table 1 for a list of means.

Accuracy measures for short SOAs show a validity effect, ($F_{(1, 11)}$=5.50; p=0.04), but no visual field effect ($F_{(1, 11)}$=1.00, p=0.34) or interaction ($F_{(1, 11)}$=2.20, p=0.17). There are no significant accuracy effects at middle range SOAs (validity: $F_{(1, 11)}$=1.00, p=0.34; visual field: $F_{(1, 11)}$=0.00, p=1.00; interaction: $F_{(1, 11)}$=1.00, p=0.34), or long SOAs (validity: $F_{(1, 11)}$=0.00, p=1.00; visual field: $F_{(1, 11)}$=0.00, p=1.00; interaction: $F_{(1, 11)}$=0.00, p=1.00). See Table 2 for a list of means.

Discussion

Experiment 1b suggests that, while a discrimination task did not produce the social gaze cuing effects with the current stimuli, a localization task is able to elucidate the normal cuing effects at some SOAs. At the earliest (50-250ms) and mid-range (300-500ms) SOAs, the reaction times to targets in valid trials (trials in which the eye gaze direction was congruent with the target location) were significantly faster than reaction times to targets in invalid trials (when the gaze and target location were incongruent). At the 50-250ms SOA, participants were also more accurate when responding to valid trials than invalid trials. There were no cuing effects present at the longest SOAs. The results of Experiment 1b suggest that using the current stimuli with a localization task produces target facilitation at the valid location for both short and mid-length SOAs. Therefore, in the following ERP experiments these two SOAs are used to explore the ERPs to targets following social gaze cues. It is important to recognize though, that previous ERP studies of social gaze cuing use an SOA slightly longer than the current middle-length SOA (500ms: Schuller and Rossion, 2001; 2004; 500-700ms: Schuller and Rossion, 2005). This need to be considered when comparing our ERPs to theirs.

CHAPTER 4

EXPERIMENT 1C: BEHAVIORAL COMPARISON OF VOLUNTARY AND SOCIAL ATTENTION

The results of Experiments 1a and 1b suggest that with the current stimuli, the social gaze cues produce no significant behavioral cuing effects with a discrimination task, but do produce significant cuing effects with a localization task. This raises the possibility of an unexpected difference between social gaze cuing and voluntary orienting, as most voluntary attention tasks employ either a discrimination task or a detection task, but none with which I am familiar use a localization task. Experiment 1c attempts to explore this possible difference using the same subjects and stimuli with both voluntary and social attention using both a discrimination task and a localization task. It is possible that the stimuli used in Experiment 1a and 1b are unable to elicit cuing effects with a discrimination task. In this experiment, we will be able explore whether the voluntary attention cues can produce cuing effects with the current stimuli which would suggest an unexpected, underlying difference between voluntary orienting and social gaze orienting.

Methods

Participants

Participants consisted of 20 undergraduate students (15 females) with a mean age of 19 years old (range:18-22). All participants had 20/20 or corrected to 20/20 vision, determined by self report. Participants were recruited through the participant pool of the

University of North Carolina at Chapel Hill. In return for their participation, they received credit towards the completion of their General Psychology class.

Materials and Procedure

Materials and procedures were similar to Experiment 1a and 1b. On all blocks, whether participants were completing a localization task or a discrimination task, targets were blue 50% of the time and purple 50% of the time. Out of a total of twenty blocks, half of the blocks used the same social gaze cues used in Experiments 1a and 1b. On one half of these social gaze blocks participant were instructed to complete a discrimination task (like in Experiment 1a) in which they responded to whether the target was blue or purple. For the other half of the social gaze cuing blocks the participants were instructed to complete a localization task (like in Experiment 1b) in which they responded to which side of the screen the target appeared. The other ten blocks used a voluntary attention cue. The background was identical to the that for the social gaze blocks, in which the male face was present at all times, but in this case, the eyes on the face were not diverted at the beginning of a trial, and instead the fixation point changed color at the beginning of the trial. The fixation changed to either red, indicating that the participant should shift attention to the right target location, or green indicating that the participant should shift attention to the left target location (See Figure 2a for an example of the voluntary cue). This cue was 75% predictive, giving the participants incentive to direct their attention to the valid side. The fixation cross then returned to black and the target ball appeared in one of the two target locations. Like in the social gaze blocks, on half of the voluntary blocks, participants were instructed to complete a discrimination task, on the other half they were instructed to complete a localization task. All blocks in this experiment used a variable SOA of 300-500ms, as this SOA successfully elicited a cuing effect for social gaze cues in Experiment 1b, and should also allow participants enough time to voluntarily shift attention before the target appears on the voluntary cuing blocks.

Data Analysis

A 2 x 2 x 2 x 2 ANOVA with factors of attention type (voluntary and social), task (localization and discrimination), validity (valid or invalid), and visual field (left and right) was conducted. Also, due to a particular interest in whether there is a cuing effect for each type of attention with each task, four separate t-test with factor of validity was conducted. Due to the increased possibility of Type I error from multiple t-tests, Benjamini-Hochberg Procedure (See Benjamini & Hochberg, 1995; Thissen et all, 2002) was completed for the t-test analysis.

Results

The ANOVA revealed a significant main effect of task ($F_{(1, 19)}$=26.3; p<0.001), visual field ($F_{(1, 19)}$=15.9; p=0.001) and, validity ($F_{(1, 19)}$=8.8; p=0.008), as well as significant interactions between attention and task ($F_{(1, 19)}$=12.1; p=0.003), attention and visual field ($F_{(1, 19)}$=18.0; p<0.001), attention, task and visual field ($F_{(1, 19)}$=7.6; p=0.013), attention and validity ($F_{(1, 19)}$=37.6; p<0.001), task and validity ($F_{(1, 19)}$=25.9; p<0.001), visual field and validity ($F_{(1, 19)}$=11.3; p=0.003), attention, visual field and validity ($F_{(1, 19)}$=9.0; p=0.007), task, visual field and validity ($F_{(1, 19)}$=27.6; p<0.001), and the four-way interaction between attention, task, visual field, and validity ($F_{(1, 19)}$=13.3; p=0.002). There was no significant interaction between attention, task and validity ($F_{(1, 19)}$=0.299; p=0.591).

For the voluntary discrimination blocks the reaction times were significantly faster for valid targets than for invalid targets (Valid=641.4ms, Invalid=715.9ms; $t_{(19)}$=3.97,

$p<0.001$. Similarly reaction times were faster for the valid targets compared to the invalid in the voluntary localization task (Valid=406.0ms, Invalid=535.6ms; $t_{(19)}=4.37$, $p<0.001$), and the social localization task (Valid=451.8ms, Invalid=479.0; $t_{(19)}=3.81$, $p<0.001$). However, there was no significant difference between valid and invalid targets for discrimination blocks using a social gaze cue (Valid=495.7ms, Invalid=604.8ms; $t_{(19)}=1.16$, $p=0.13$).

Discussion

The results of Experiment 1c raise the possibility of an unexpected behavioral difference between voluntary and social gaze orienting. This experiment provides evidence that, with the current stimuli, voluntary attention produces a significant cuing effect with both localization and discrimination tasks, while social gaze orienting only produces cuing effects with a localization task, and not a discrimination task. It seems that localization and discrimination tasks may require different underlying processes that are differentially activated by voluntary and social attention cues. For example, discrimination of a target may require greater recruitment of the ventral "what" pathway allowing for the identification of certain features needed to make a given discrimination, while a localization task may require more recruitment of the dorsal "where" pathway. It seems possible that social gaze cues and voluntary attention cues may prime these systems in different ways, or at different stage of visual processing. This could lead to facilitation of processing is some instances or tasks, but not in others. For example, perhaps voluntary attention exerts its effect early on in visual processing before the dorsal and ventral steams split, leading to facilitation for either stream, where social attention may not exert its effects until further down the dorsal steam leading to facilitation only on tasks which recruit this visual pathway. It is also, however, important to recognize the possibility that localization and discrimination tasks may show such marked differences between voluntary and social attention due the fact that the discrimination task is simply more difficult. While there was a significant cuing effect for voluntary attention with the discrimination task, there was a larger cuing effect for the voluntary attention with the localization task. It is possible that the cuing effect for the social discrimination task is just too small to be significant. Further exploration is needed to better understand the underlying differences. ERPs can give us some understanding of the underlying neural differences between the different types of attention.

CHAPTER 5

EXPERIMENT 2: ERPS OF SOCIAL, VOLUNTARY, AND REFLEXIVE ATTENTION AT THE SAME SOA

Experiment 2 directly compares the neural activity evoked by peripheral targets following reflexive, voluntary, and social gaze cues. While all produce behavioral facilitation at the valid location at certain SOAs, previous ERP studies exploring each of these types of attention separately suggest that the visually evoked ERPs produced by targets preceded by each of the cues may be different. Here the visually evoked ERPs for targets following each of these types of cue are directly compared within the same subjects using the same stimuli and task.

Exploring ERPs for these three types of attention provides a greater understanding of how social gaze orienting relates to each of the other types of widely studied attention. ERP studies of social gaze orienting alone have raised the possibility that facilitory behavioral effects of faster reaction times and/or greater accuracy are associated with latency shifts as well as amplitude differences (Schuller & Rossion, 2001; 2004). Both reflexive and voluntary orienting, however, have strictly produced amplitude differences in ERPs to target processing. In the studies of social gaze processing, Schuller and Rossion (2001; 2004) used a localization task with fixed SOAs of 500 ms, while most voluntary studies use longer SOAs and most reflexive studies use either shorter SOAs (to produce facilitation) or longer SOAs (to produce IOR). This study will use the mid-range SOA (300-500ms), which was found to be successful at elucidating the social cueing effect in Experiment 1b, for all three types of attention in a within subjects design. This provides a control for possible timing and group differences in previous studies. Using the same timing in the gaze cue blocks as in the other blocks also allows us to conclude that any ERP differences we find are not be due to timing differences that may affect the alertness of the participants on each trial. For example, if there is 300ms between the cue and target in social gaze trials and 700ms between the cue and target in voluntary orienting trials, there could possibly be differences in alertness when the target appears. If the participants are more alert during one task, it could lead to a greater focus of attention which could produce reduced reaction times, and bigger attention effects in the ERP components of interest.

Methods

Participants

Twenty-one healthy young adults participated in this study and were paid $10 per hour. Participants had 20/20 or corrected-to-20/20 vision and no known neurological problems. Five participants' data were not usable due to errors in data acquisition and/or excessive artifacts; therefore, the final analysis included data from 16 participants (7 female) with a mean age of 22.6 years old (range: 18-28).

Materials and Procedure

The experiment consisted of three different types of blocks: (1) social gaze orienting blocks, (2) reflexive orienting blocks, and (3) voluntary orienting blocks. The social gaze orienting blocks used the same set of stimuli as Experiments 1a, 1b, and 1c (See Figure 1). An SOA of 300-500ms is used for each of the different types of attention blocks. This SOA produced significant social gaze cueing effects in Experiment 1b and is closest to the timing used by Shuller and Rossion (2001; 2004; 2005) in previous social gaze cuing ERP studies.

The reflexive orienting blocks used stimuli similar to those used on the gaze orienting blocks, except that the face in the center of the screen kept its gaze directed straight ahead through the entire block. At the beginning of a trial, the reflexive cue, consisting of a white ring in one of the two possible target locations, appeared on the screen for 34ms, followed by the background screen for 266-466ms, after which a target, consisting of a large blue ball appeared for 100ms. Participants were required to respond to the location of the ball indicating whether it appeared in the left or right visual field with the press of a button on a game pad. The ITI, during which the background screen with neither the cue stimulus nor the target stimulus appeared, was 2000-2500ms. (See Figure 2b for an example of the reflexive cue).

The blocks exploring voluntary orienting used the same stimuli as voluntary blocks in Experiment 1c.The fixation point changed color at the beginning of the trial for 300-500ms. The fixation changed to either red, indicating that the participant should shift attention to the right target location, or green indicating that the participant should shift attention to the left target location. This cue was 75% predictive, giving the participants incentive to direct attention to the valid side. Then the fixation cross then returned to black and a target ball appeared in one of the two target locations. Participants were required to respond with one button if the target appeared on the left and another if it appeared on the right. The ITI for the voluntary blocks was 2000-2500ms. (See Figure 2a for an example of the voluntary cue).

Recording and Analysis

While participants completed the localization task, accuracy data and reaction times were collected, as well as EEG from 96 electrode sites. The EEG is referenced to the right mastoid, amplified at a bandpass of 0.05-100 Hz and digitized at 250 samples per second. Eye-movements were observed throughout all blocks with the use of a camera, and electrodes located beneath and lateral to the outer canthus of each eye recorded the electro-oculogram. All trials containing eye movements or blinks were rejected off-line and not included in the analysis. EEG data was averaged to create ERP waveforms. The data was low-pass filtered to remove high-frequency noise and high-pass pass filtered with a single-pole causal filter to reduce low frequency drifts. Because the cues and targets in each of the types of blocks occur temporally close to one another, the Adjar technique was used to remove overlapping activity by convolving the cue and target waveforms with previous and subsequent event distributions (Woldorff, 1993). This technique has been used previously to successfully remove the overlap in waveforms (Hopfinger & Mangun, 1998, 2001; Woldorff, 1993; Hopfinger & West, 2006). Ten iterations of the Adjar filter were applied to individual participant averages before the participants data was averaged together.

For the ERP data, a 4-factor ANOVA with factors of attention type, validity, visual field, and electrode was conducted for amplitude and latency of the P1 and N1 components and the amplitude of the P2, P300, and N400 components. Target prepossessing in the ipsilateral hemisphere is not well understood and occurs at a slightly later latency than processing in the contralateral hemisphere. Therefore, the current study, for the P1 and N1 components, analysis will concentrate on target processing in the hemisphere contralateral to the target. The electrodes to be tested are picked based on topographic maps of the data which allow a visualization of where on the head the component is peaking. After collapsing the data by visual field, the four electrodes (2 for each visual field) closest to the peak of the activity on the scalp contralateral to the stimulus, as well are those that are used in the subsequent analysis. Also, for the P1 and N1 ERP components, the amplitude and latency will be explored so these measures can be compared to previous studies. For the later latency components however, only the amplitude with be tested as with these broader components, it is not always clear what should be considered the peak of the component as the peaks are often imprecise and more affected by the low-pass filter.

Results

Behavioral Results

For reaction time measures, a 3 x 2 x 2 ANOVA with factors of attention type, visual field and validity revealed a significant main effect of attention type (Social=315.1ms, Voluntary=327.9ms, Reflexive=317.9ms; $F_{(2, 14)}$=5.57, p=0.009), a significant main effect of validity (Valid=300.4ms, Invalid=340.2ms; $F_{(1,15)}$=43.76, p<0.001), a significant interaction between attention type and validity ($F_{(2,14)}$=12.22; p<0.001), an interaction between attention type and visual field ($F_{(2,14)}$=4.60; p=0.018), an interaction between visual field and validity ($F_{(1,15)}$=11.94; p=0.004), and finally a significant 3-way interaction between attention type, visual field and validity ($F_{(2,14)}$=4.44; p=0.021).

In order to better understand how the current results relate to previous studies in which each type of attention was studied separately, 2 x 2 ANOVAs with factors of visual field and validity were conducted for each type of attention separately. Social attention blocks showed a validity effect (Valid=300.8ms, Invalid=329.4ms; $F_{(1,15)}$=21.51, p<0.001), and a significant effect of visual field (RVF=322.6ms, LVF=307.6ms; $F_{(1, 15)}$=8.75, p=0.010), but no interaction between the factors ($F_{(1, 15)}$=1.43, p=0.25). For voluntary attention blocks there was a significant effect of validity (Valid=282.1ms, Invalid=373.8ms; $F_{(1, 15)}$=24.37, p<0.001), and a significant interaction between validity and visual field with the validity effect being larger for left visual field targets (Valid RVF=288.7ms, Valid LVF=275.4ms, Invalid RVF=380.0, Invalid LVF=367.5; $F_{(1, 15)}$=7.07, p=0.018). For reflexive attention blocks there was no validity effect (Valid=318.4ms, Invalid=317.4ms; $F_{(1, 15)}$=0.02, p=0.888), but there was a significant interaction between visual field and validity (Valid RVF=320.9ms, Valid LVF=315.8ms, Invalid RVF=324.7ms, Invalid LVF=310.1ms; $F_{(1, 15)}$=6.28, p=0.024). (See Table3 for a complete list of means.)

For accuracy measures, a 3 x 2 x 2 ANOVA with factors of attention type, visual field, and validity revealed a significant main effect of attention type (Social=98.2%, Voluntary=96.0%, Reflexive=98.2%; $F_{(2, 14)}$=9.61, p=0.001), a significant main effect of validity (Valid=98.5%, Invalid=96.4%; $F_{(1,15)}$=14.15, p=0.002), and a significant interaction between attention type and validity ($F_{(2,14)}$=8.05; p=0.002).

Again, a 2 x 2 ANOVA with factors of visual field and validity was conducted for each type of attention separately. Social attention blocks showed a validity effect (Valid=98.7%, Invalid=97.7%; $F_{(1,15)}$=10.33, p=0.006), but no other main effects or interactions. For voluntary attention blocks there was a significant effect of validity (Valid=98.6%, Invalid=93.4%; $F_{(1, 15)}$=10.62, p=0.005), a trend for left visual field targets responses to be more accurate (RVF=95.3%, LVF=96.7%; $F_{(1, 15)}$=3.68, p=0.074), and a significant interaction between validity and visual field ($F_{(1, 15)}$=4.57, p=0.049). For reflexive attention blocks there was no validity effect (Valid=98.2%, Invalid=98.2%; $F_{(1, 15)}$=0.00,

p=0.964), and no other main effects or interactions. (See Table 3 for a complete list of the means).

ERP results

P1: Amplitude

For the amplitude of the P1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type (social, voluntary, and reflexive), validity (valid and invalid), visual field (right visual field and left visual field), and electrode [E(electrode) 47/47 and E51/52] was conducted with a 20ms time window around the peak. The peak varied between each type of attention. A time range of 86-106ms was used for social attention, 82-102ms for voluntary attention, and 78-98ms for reflexive attention. This ANOVA revealed a significant main effect of attention type (Social=1.53µv, Voluntary=1.56µv, Reflexive=0.92µv; $F_{(2, 14)}$=10.21, p<0.001), as well as significant main effect of visual field (RVF=0.90µv, LVF=1.78µv; $F_{(1, 15)}$=7.90, p=0.013). There was no significant main effect of validity (Valid=1.30µv, Invalid=1.38µv; $F_{(1, 15)}$=0.68, p=0.423). (See Figure 3 for plots of early attention effects).

Again, 2 x 2 x 2 ANOVAs were conducted for each type of attention separately to allow comparison to previous ERP studies, most of which explore one type of attention alone. For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a near significant effect of visual field (RVF=1.10µv, LVF=1.96µv; $F_{(1, 15)}$=4.06, p=0.062). There was no significant main effect of validity (Valid=1.48µv, Invalid=1.58µv; $F_{(1, 15)}$=0.40, p=0.574). (See Figure 4 for plots and Figure 5 for topography of the P1 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of visual field (RVF=1.03µv, LVF=2.08µv; $F_{(1, 15)}$=9.40, p=0.008), as well as a main effect of electrode (E47/48=1.44μv, E51/52=1.68μv; $F_{(1, 15)}$=9.05, p=0.009). There was no significant main effect of validity (Valid=1.55μv, Invalid=1.56μv; $F_{(1, 15)}$=0.00, p=0.966). (See Figure 6 for plots and Figure 7 for topography of the P1 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of visual field (RVF=0.56μv, LVF=1.28μv; $F_{(1, 15)}$=7.79, p=0.014). There was no significant main effect of validity (Valid=0.85μv, Invalid=0.99μv; $F_{(1, 15)}$=0.40, p=0.534). (See Figure 8 for plots and Figure 9 for topography of the P1 component for reflexive blocks; See Appendix for complete ANOVA tables).

P1: Latency

For the latency of the P1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type, validity, visual field, and electrode revealed a significant main effect of attention type (Social=96.4ms ,Voluntary=91.6ms, Reflexive=88.4ms; $F_{(2, 14)}$=13.38, p<0.001). There was no significant effect of validity (Valid=91.3ms, Invalid=92.9ms, $F_{(1, 15)}$=1.44, p=0.557), but there was a significant interaction between validity and visual field (Valid Right=88.3ms, Invalid Right=91.5ms, Valid Left=94.3ms, Invalid Left=94.3ms; $F_{(1, 15)}$=5.48, p=0.034). (See Figure 3 for plots of early attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a trend for a main effect of validity (Valid=95.6ms, Invalid=98.1ms; $F_{(1, 15)}$=4.10, p=0.061). (See Figure 4 for plots and Figure 5 for topography of the P1 component for social attention blocks). There were no other main effects or interactions. For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed no significant main effect of validity (Valid=91.4ms, Invalid=91.2ms; $F_{(1,}$

$_{15)}$=0.03, p=0.860) or any other main effects or interactions. (See Figure 6 for plots and Figure 7 for topography of the P1 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a near significant effect of visual field (RVF=84.4ms, LVF=88.3ms; $F_{(1, 15)}$=4.48, p=0.052). There was no significant main effect of validity (Valid=86.3ms, Invalid=86.4ms; $F_{(1, 15)}$=0.00, p=0.959). (See Figure 8 for plots and Figure 9 for topography of the P1 component for reflexive blocks; See Appendix for complete ANOVA tables).

N1: Amplitude

For the amplitude of the N1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 47/47 and electrode 89/90) was conducted with a 20ms time window around the peak. The peak varied between each type of attention. A time range of 142-162ms was used for social attention, 133-153ms for voluntary attention, and 133-153ms for reflexive attention. The ANOVA revealed a significant main effect of visual field (RVF=-0.06µv, LVF=-1.03µv; $F_{(1, 15)}$=15.14, p=0.001) as well as a significant interaction between attention type and validity (Social Valid=-0.46µv, Social Invalid=-0.31µv, Voluntary Valid=-0.83µv, Voluntary Invalid=-0.90µv, Reflexive Valid=-0.66µv, Reflexive Invalid=-0.12µv; $F_{(2, 14)}$=3.98, p=0.029) and a significant interaction between attention type and visual field (Voluntary RVF= -1.01µv, Voluntary LVF= -0.72µv, Reflexive RVF=0.46µv, Reflexive LVF=-1.24µv, Social RVF=0.36µv, Social LVF=-1.13µv; $F_{(2,14)}$= 10.09, p<0.001). There was no significant main effect of attention type (Social=-0.39µv, Voluntary=-0.87µv, Reflexive=-0.39µv; $F_{(2, 14)}$=1.96, p=0.158) or validity (Valid=-

0.65µv, Invalid=-0.44µv; $F_{(1, 15)}$=1.92, p=0.186). (See Figure 3 for plots of early attention effects).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.35, p=0.562). An ANOVA with reflexive and social attention similarly revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 2.33, p=0.148). An ANOVA with reflexive and voluntary attention did show a significant interaction between attention and validity ($F_{(1, 15)}$= 12.45; p=0.003).

Separate 2 x 2 x 2 ANOVAs with factors of validity, visual field, and electrode for each type of attention separately show no significant effect of validity for social attention blocks (Valid=-1.23µv, Invalid=-1.13µv; $F_{(1, 15)}$=0.13, p=0.722) (See Figure 4 for plots and Figure 5 for topography of the N1 component for social attention blocks) or voluntary attention blocks (Valid=-0.83µv, Invalid=-0.90µv; $F_{(1, 15)}$=0.14, p=0.714) . (See Figure 6 for plots and Figure 7 for topography of the N1 component for voluntary attention blocks). The 2 x 2 x 2 ANOVA conducted for reflexive attention blocks did show a significant effect of validity (Valid=-1.69µv, Invalid=-1.13µv; $F_{(1, 15)}$=10.32, p=0.006). (See Figure 8 for plots and Figure 9 for topography of the N1 component for reflexive blocks; See Appendix for complete ANOVA tables).

N1:Latency

For the latency of the N1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type, validity, visual field, and electrode revealed a significant main effect of visual field (RVF=150.4ms, LVF=143.2ms; $F_{(1, 15)}$=7.47, p=0.015), a significant main effect of electrode (E47/48=148.8ms, E89/90=144.9ms; $F_{(1, 15)}$=12.43, p=0.003), and a significant interaction between visual field and electrode (RVF E47/48=153.0ms, RVF E89/90=147.8ms, LVF E47/48=144.5ms, LVF E89/90=141.9ms, $F_{(1, 15)}$=5.18, p=0.038). There was no significant main effect of attention type (Social=151.6ms, Voluntary=143.3ms, Reflexive=145.5ms; $F_{(2, 14)}$=1.73, p=0.194) or validity (Valid=144.9ms, Invalid=148.7ms; $F_{(1, 15)}$=1.81, p=0.199). (See Figure 3 for plots of early attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a small, but significant main effect of validity (Valid=146.6ms, Invalid=148.7ms; $F_{(1, 15)}$=6.7, p=0.021) as well as a main effect of electrode (E47/48= 148.3ms, E89/90=146.9ms; $F_{(1, 15)}$=8.77, p=0.010). There were no other main effects or interactions. (See Figure 4 for plots and Figure 5 for topography of the N1 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a small, but significant main effect of validity (Valid=139.6ms, Invalid=141.6ms; $F_{(1, 15)}$=8.57, p=0.010) and a main effect of electrode (E47/48= 141.3, E89/90=140.0; $F_{(1, 15)}$=7.98, p=0.013). There were no other significant main effects or interactions. (See Figure 6 for plots and Figure 7 for topography of the N1 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of electrode (E47/48=143.4ms, E89/90=141.4ms; $F_{(1, 15)}$=16.55, p=0.001). There was no significant main effect of validity (Valid=141.5ms, Invalid=143.3ms; $F_{(1, 15)}$=1.24, p=0.283). There were no other main effects or interactions. (See Figure 8 for plots and Figure 9 for topography of the P1 component for reflexive blocks; See Appendix for complete ANOVA tables).

P2: Amplitude

While exploring the P300 component in the current data set, it became evident from looking at the plots that there another component present in between the N1 and the P300 component; there was a faster, earlier, positive component, which was not initially expected in the current study, but similar to the P2 component that has been explored in previous studies, including some attention paradigms. For the amplitude of the P2 ERP component, a 3 x 2 x 2 x 3 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 82 and electrode 83) was conducted with a 20ms time window around the peak. The peak varied between each type of attention and validity. A time range of 170-190ms was used for valid trials with social attention, 190-210ms for invalid trails with social attention, 170-190ms for valid trials with voluntary attention, 190-210ms for invalid trials with voluntary attention, 170-190ms for valid trials on reflexive attention, and 185-195ms for invalid trials with reflexive attention.

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.44, p=0.519). An ANOVA with reflexive and social attention revealed a significant interaction between attention and validity ($F_{(1, 15)}$= 8.08, p=0.012). An ANOVA with reflexive and voluntary attention showed a significant interaction between attention and validity ($F_{(1, 15)}$= 24.99; p<0.000) as well.

The ANOVA revealed a significant main effect of attention type (Social=2.40μv, Voluntary=2.45μv, Reflexive=1.66μv; $F_{(2, 14)}$=6.95, p=0.003). While there was no significant main effect of validity (Valid=2.24μv, Invalid=2.10μv; $F_{(1, 15)}$=0.61, p=0.448), there was a significant interaction between attention type and validity (Voluntary Valid=2.95μv, Voluntary Invalid=1.95μv, Reflexive Valid=1.05μv, Reflexive Invalid=2.26μv, Social Valid=2.72μv, Social Invalid=2.10μv; $F_{(2, 14)}$=9.41, p<0.001), and an interaction between attention type and electrode (Voluntary E82=2.33μv, Voluntary E83=2.58μv, Reflexive E82=1.65μv, Reflexive E83=1.66μv, Social E82=2.23μv, Social E83=2.51μv; $F_{(2, 14)}$=5.81, p=0.007). (See Figure 10 for plots of late attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode showed no significant main effect of validity (Valid=2.73μv, Invalid=2.07μv; $F_{(1, 15)}$=2.63, p=0.123). (See Figure 11 for plots and Figure 12 for topography of the P2 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of validity (Valid=2.95μv, Invalid=1.95μv; $F_{(1, 15)}$=10.52, p=0.005). (See Figure 13 for plots and Figure 14 for topography of the P2 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with the same factors revealed a significant effect of validity (Valid=1.05μv, Invalid=2.26μv; $F_{(1, 15)}$=9.90, p=0.007). (See Figure 15 for plots and Figure 16 for topography of the P2 component for reflexive attention blocks; See Appendix for complete ANOVA tables).

P300 Amplitude

For the amplitude of the P300 ERP component, a 3 x 2 x 2 x 3 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 69, electrode 70 and electrode 85) was conducted with a 20ms time window around the peak. The peak varied between each type of attention and validity. A time range of 240-260ms was used for valid trials with social attention, 290-310 for invalid trials with social attention, 280-300ms for valid trials with voluntary attention, 290-310ms for invalid trials with voluntary attention, 270-290ms for valid trials with reflexive attention, and 240-260ms for invalid trials with reflexive attention. The ANOVA revealed a significant main effect of validity (Valid=2.48μv, Invalid=3.04μv; $F_{(1, 15)}$=9.21, p=0.008). There was also a significant interaction between attention type and validity (Voluntary Valid=2.20μv, Voluntary Invalid=3.66μv, Reflexive Valid=2.66μv, Reflexive Invalid=2.40μv, Social Valid=2.60μv, Social Invalid=3.07μv; $F_{(2, 14)}$=3.94, p=0.030), and an interaction between attention type and electrode ($F_{(2, 14)}$=2.83, p=0.032). (See Figure 10 for a plot of late attention effects).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 3.05, p=0.101). An ANOVA with reflexive and social attention similarly revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.86, p=0.368). An ANOVA with reflexive and voluntary attention did show a significant interaction between attention and validity ($F_{(1, 15)}$= 15.45; p=0.001).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed no significant main effect of validity (Valid=2.60μv, Invalid=3.07μv;

$F_{(1, 15)}$=1.24, p=0.283), but there was a significant interaction between validity and electrode $F_{(2, 14)}$=6.15, p=0.006). (See Figure 11 for plots and Figure 12 for topography of the P300 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of validity (Valid=2.20µv, Invalid=3.66µv; $F_{(1, 15)}$=27.33, p<0.001). (See Figure 13 for plots and Figure 14 for topography of the P300 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with the same factors revealed no significant main effect of validity (Valid=2.66µv, Invalid=2.40µv; $F_{(1, 15)}$=0.35, p=0.564). (See Figure 15 for plots and Figure 16 for topography of the P300 component for reflexive attention blocks; See Appendix for complete ANOVA tables).

N400 Amplitude

Like the P2 component, attention differences in a late negative component occurring after the P300 were not expected. For the amplitude of this component, referred to as an N400 from here on, a 3 x 2 x 2 x 3 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 69, electrode 70 and electrode 85) was conducted with a 20ms time window around the peak. The peak varied between each type of attention and validity. A time range of 410-430ms was used for valid trials with social attention, 410-430ms for invalid trials with social attention, 405-425ms for valid trials with voluntary attention, 400-420ms for invalid trials with voluntary attention, 470-490ms for valid trials with reflexive attention, and 450-470ms for invalid trials with reflexive attention. The ANOVA revealed a significant interaction between attention type and validity (Social Valid=-0.20µv, Social

Invalid=-0.58µv, Voluntary Valid=-1.04µv, Voluntary Invalid=-0.39µv, Reflexive Valid=-0.96µv, Reflexive Invalid=0.60 µv; $F_{(2, 14)}$=7.31, p=0.003). (See Figure 10 for a plot of late attention effects).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and reflexive attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.81, p=0.382). An ANOVA with reflexive and social attention revealed a significant interaction between attention and validity ($F_{(1, 15)}$= 6.75, p=0.020). An ANOVA with voluntary and social attention did show a significant interaction between attention and validity ($F_{(1, 15)}$= 24.84; p<0.001).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode showed that invalid trials produced a significantly larger N400 than valid trials (Valid=-0.20µv, Invalid=-0.58µv; $F_{(1, 15)}$=4.78, p=0.045). (See Figure 11 for plots and Figure 12 for topography of the N400 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of validity in the opposite direction (Valid=-1.04µv, Invalid=-0.39µv; $F_{(1, 15)}$=14.91, p=0.002). (See Figure 13 for plots and Figure 14 for topography of the N400 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with the same factors revealed no significant main effect of validity (Valid=-0.96µv, Invalid=-0.60µv; $F_{(1, 15)}$=2.11, p=0.167). (See Figure 15 for plots and Figure 16 for topography of the N400 component for reflexive attention blocks; See Appendix for complete ANOVA tables).

Discussion

While social gaze cue orienting is often talked about as an automatic, reflexive form of attentional orienting, the results of the current study suggest that social gaze orienting is actually more similar to the classically defined voluntary attention than to the classically defined reflexive attention in terms of behavioral performance, early visual processing, and slightly later, higher-order visual processing. As expected, the reaction time measures for social gaze cue blocks showed a significant effect of validity in which the valid targets were responded to more quickly than invalid targets. These behavioral effects were exhibited in the ERPs by a decreased latency of the P1 and N1 ERP components, but there were no significant differences between valid and invalid targets on the amplitude of these components. The latency shifts of the early processing components are similar to those found by Shuller and Rossion (2001; 2004; 2005), but Shuller and Rossion also reported main effects of validity on the amplitude of these components (2001; 2005). It is important to recognize, however, that one study by the same group did not find a significant main effect of validity on the amplitude of the P1 or the N1 (Shuller and Rossion, 2004). They found an interaction in which only the right hemisphere showed significant validity effects. The only differences between the studies in which they did find significant main effects of validity and the one in which they did not, was (1) the face appeared with the eyes already diverted, and (2) there were neutral trials in which the eyes gazed straight ahead. It is not clear why either of these differences would reduce cuing effects which raises the possibility that these amplitude differences are not easily elucidated with a localization task and that they may be very sensitive to small stimulus differences. For example, the use of a computer generated face, place holders for the targets, and timing differences may have lead to the differing results between the current study and those conducted by Shuller and Rossion (2001; 2004; 2005).

Similarly to the social blocks, the voluntary cuing blocks in which participants were voluntarily directing their attention to the possible target locations produced the normal and expected behavioral effect of shorter reaction times when the target appeared at the valid location compared to when it occurred at the opposite location. This suggests that even though the SOA was shorter than is often used in voluntary cuing paradigms, participants were allowed enough time to shift their attention before the target appeared allowing enhanced processing of the target. The enhanced processing of the target however, was, like in the social blocks, not exhibited in the amplitude of either the P1 or N1 ERP component, as there was no significant validity effect for the amplitude of either of these components. Modulation of these components is often found in voluntary cuing paradigms. The current study, unlike most previous voluntary cuing studies, used a localization task in which participants were required to respond to the location of the target on each trial. This raises the interesting possibility that reason no amplitude effects are observed is due the use of a localization task. As reported previously, some studies suggest that the size of the P1 and N1 amplitude effects are affected by task difficulty and/or visual load (e.g. Handy and Mangun, 2000; Vogel and Luck, 2000). It is possible that the localization task and the targets used here are too simple to evoke the validity effects normally observed with voluntary attention. There was also no validity effect for the latency of the P1, but interestingly, like in social cuing blocks, the N1 component occurred significantly sooner for valid trials compared to invalid trials, a finding not previously reported in voluntary cuing paradigms. This small but significant effect could be due to the use of a localization task, as well. Latency effects have previously been found for target processing following social gaze cues in studies in which a localization task was used (Shuller and Rossion, 2001; 2003; 2005), but are not typically found in voluntary and reflexive cuing paradigms.

As expected, reflexive attention produced no significant main effect of validity for reaction times. The SOA range used in the current experiment was slower than that usually used to explore facilitation of target processing following reflexive cues, and faster than that usually used to explore IOR following a reflexive cue. Of the sixteen participants analyzed in the current study, only four showed positive cuing effects greater than 20ms and only four showed inhibitory cuing effects of greater than 20ms, suggesting the SOA was between that which produces facilitation and that which produces IOR for half of the participants. Similarly, the amplitude and the latency of the P1 component showed no effect of validity. While there was no effect of validity on the latency of the N1 component, the amplitude of the N1 component was significantly greater for valid trials compared to invalid trials.

Previously, reflexive attention cues have produced a greater amplitude N1 component for invalid targets at SOAs that produce facilitation, and a greater amplitude N1 component for valid targets at SOAs that produce IOR (e.g. Hopfinger and Mangun, 1998; 2001). Rather than providing evidence of an enhancement of processing at levels of processing indexed by the N1, it has been suggested that it is in fact evidence of an extended positivity overlapping with the late stages of the P1 component (e.g. McDonald et al., 1999; Hopfinger and Ries, 2005). This would suggest, while neither facilitation nor IOR was observed with reaction time measures, inhibition of valid targets may be beginning to occur with the current SOA range. This suggests that we are able to see evidence of IOR in the neural responses even before robust behavioral effects of IOR are seen.

Exploration of each type of attention, suggests that both voluntary and social attention cues are able to produce faster reaction times at the 300-500ms SOA and are associated primarily with latency shifts at the early levels of processing indexed by the P1 and N1 ERP components. Reflexive orienting did not produce behavioral effects at this SOA and was associated exclusively with amplitude differences at early levels of processing indexed by the later stages of the P1 component and the N1 component. ANOVAs including the factor of attention type, point to main effects of attention on behavior as well as amplitude and latency of some ERP components. Specifically, there was a main effect of attention on reaction time in which targets in the voluntary attention blocks are responded to more slowly than those in the social and reflexive blocks. Even though reaction times were delayed for voluntary attention compared to social and reflexive attention, the early visual processing of the stimuli was similar for voluntary and social attention. The main effect of attention type on the amplitude of the P1 component suggests that at this early stage of processing, target processing is similar for voluntary and social attention, both of which produce larger amplitude P1 components than reflexive attention. There is also a main effect of attention type for the latency of the P1 component. The reflexive P1 has the shortest latency, and voluntary and social targets longer latency P1 component. The enhanced amplitude of the P1 component for targets following voluntary and social cues suggests targets may be perceived as more salient in these conditions which could explain the larger behavioral effects. These effects of attention type on the early visual components suggest that, although the timing between the cue and target onset is the same for each type of attention, the cues may prepare the participants differently for the following target.

While the behavioral measures and the early visual components suggest large differences between social attention and reflexive attention, perhaps the most interesting results come from the later, higher-order processing, in which unexpected differences between attention types emerged. Upon visual inspection of the long, slow, P300 wave, it became evident that a faster component was overlapping with the early stages of the P300, and this wave was showing different effects of validity than the P300. Closer inspection of the topographies of these components, provide more evidence that they are two separate components. The earlier P2 component has a more anterior distribution with an orientation stretching from anterior sites back toward posterior sites along the central electrodes. The later P300 component however, is generally more posterior than the P2, and has an orientation stretching from left hemisphere sites, across central sites, to right hemisphere sites. These variations in topography suggest the possibility of different underlying neural generators, giving rise to varying functions.

The P2 component has been associated with various processes of target evaluation (Song et al., 2006). Specifically, in adults, larger P2 components have been found with ignored sounds compared to attended sounds (Wetzel et al., 2006). One previous study found that P2 effects were enhanced for targets that were preceded by a non-informative cue compared to a valid or invalid cue (Talsma, 2005). This is relevant to the current study as the two types of cues that were not predictive and that participants were told ignore (reflexive and social) produced validity effects opposite from the voluntary cues, which were predictive of where the target would appear. Specifically, valid trials produced a significantly larger P2 component than invalid trials for voluntary attention. The opposite was true for reflexive attention blocks in which the P2 amplitude was significantly larger for invalid trials than for valid trials. While the validity effect on the P2 was not significant for social attention, the trend was in the same direction as voluntary attention. Based on the studies that show ignored stimuli produce an enhance P2, one would expect an overall enhancement for both reflexive and social attention blocks, but since these responses are to the targets and not the cues, this P2 effect suggests that the different types of cues may differentially affect the alertness for valid and invalid trials.

The P300 component showed different effects than the P2. The voluntary attention blocks produced a larger amplitude P300 component for invalid trials than for valid trials. Most likely, this is due to the predictability of the voluntary cue. Only 25% of all trials in this condition were invalid making an invalid target an infrequent and odd event. As stated previously, an oddball task in which an infrequent target is presented amongst a frequent distracter, the odd, or infrequent stimuli produce a larger P300 component than the frequent stimuli. When a very novel stimulus, such as picture of an animal amongst simple circle distracters and square targets, occurs in the oddball paradigm a more anterior P3a is elicited. Viewing the topography of the P300 effect for voluntary attention leads to the conclusion that the increased P300 for invalid targets is probably a P3a component as the distribution is much more anterior than the P300 distribution for any other condition. This suggests that, while both voluntary and social attention show similar P300 effects of invalid trials producing larger P300 components, the P300 elicit by the voluntary attention blocks, seems to be a different process. The distribution of the P300 component for voluntary orienting, suggests that the invalid trials are perceived as novel, while the P300 for social attention blocks has a more posterior P300, suggesting that something about the cue cause the invalid trials to seem more task relevant, but not necessarily novel.

The late negative component occurring after the P300, is perhaps the most interesting finding as it shows a social validity effect distinct from both voluntary and reflexive attention as the amplitude is increased for invalid trials. This component occurs at a similar time and has a similar topography to the N400 ERP component discussed in the language literature. The N400 in the language literature is classically enhanced to sentences in which the final word is anomalous (e.g. Kutas & Hillyard, 1980; 1984). This suggests that the incongruent target is not expected and therefore may seem odd, or out of place. It is not clear however, why the voluntary attention blocks would produce a larger N400 for valid trials as valid trials would be more expected than invalid trials.

The results of Experiment 2 suggest that at early levels, the effects of social attention cues are very similar to the effects elicited by voluntary cues than those of reflexive attention when stimuli and timing are the same. The behavioral effects, as well as the early visual processing effects indexed by the P1 and N1 components are similar for voluntary and social attention, as both exhibit latency shifts, but are very different for reflexive attention, which primarily elicits amplitude effects. On the surface, it also seems that higher-level processing indexed by the P300 component is similar for voluntary and social attention, but a closer look shows that the distribution of the P300 component across the scalp is very different for voluntary invalid trials and social invalid trials. Interestingly, two unexpected ERP components were elicited and provided more evidence that social gaze orienting is a separate attentional process. The N400 component was particularly interesting as it was the only ERP component to show distinct processing for social attention, in that the amplitude of the N400 was enhanced for invalid trials.

This experiment explored these types of attention controlling for SOA. It seems possible, though, that the reason reflexive attention produces such dramatically different ERP effects, is due the fact that the timing used here is able to produce facilitation of target processing for voluntary and social cues, but not reflexive cues. The following study explores these same effects when each type of attentional cue is able to produce robust behavioral facilitation.

CHAPTER 6

EXPERIMENT 3: ERPS OF SOCIAL, VOLUNTARY, AND REFLEXIVE ATTENTION AT FACILITORY TIMING

The primary purpose of this experiment is to explore the differences between the three types of attention, when they are producing their maximum facilitory effects on behavior. Experiment 2 explored the neural underpinnings of the three types of attention, with each type using the same cue-target SOA. However, the maximum facilitory effects of each of the three types of cue should occur at different times, with reflexive attention and social gaze cuing occurring quickly, and voluntary orienting occurring later and for the longest period of time. The results of Experiment 2 are useful in understanding how social gaze orienting is separate from the other types when similar timing is used, while this experiment makes the behavioral effects more similar in order to examine whether the underlying neural response is similar as well. By exploring the differences in neural activity associated with similar behavioral outcomes, we gain further understanding of how social gaze orienting relates to reflexive and voluntary attention, and more specifically, if it is just part of one or both of these types of orienting simply being activated with a different type of cue.

Methods

Participants

Seventeen participants were recruited from flyers and mass-email distributed to students at the University of North Carolina at Chapel Hill. They received $10/hour of participation. The experiment lasted about three hours for each participant. One participant's data was not used due to excessive eye-blinks. Therefore, the final analysis included data from 16 participants (7 female) with a mean age of 22.8 years old (range=18-29).

Materials and Procedure

Materials and procedure are identical to Experiment 2 with the exception of the timing within each type of block. Rather than using the same timing in the voluntary, reflexive, and social gaze paradigms, timing that produced facilitation of visual processing for each type of orienting in pilot testing was used. For voluntary attention, a longer cue-target SOA of 600-800ms was used, while both reflexive attention and social gaze orienting blocks used an SOA of 50-250ms. The was the SOA that was found to produce the most robust effects for social gaze orienting with our stimuli in Experiment 1b, as it produced significant cuing for both reaction time and accuracy.

Recording and Analysis

The ERP recording and analysis was the same as in Experiment 2.

Results

Behavioral Results

For reaction time measures, a 3 x 2 x 2 ANOVA with factors of attention type, visual field and validity revealed a significant main effect of validity (Valid=319.9ms, Invalid=373.9ms; $F_{(1,15)}$=50.7, p<0.001), as well as a significant interaction between attention type and validity ($F_{(1,14)}$=5.28; p=0.011). Separate 2 x 2 ANOVAs with factors of visual field and validity for each type of attention separately revealed a significant effect of validity for voluntary attention (Valid=295.6, Invalid=400.7; $F_{(1, 15)}$=18.4, p=0.001), reflexive attention (Valid=338.3, Invalid=360.8; $F_{(1, 15)}$=10.0, p=0.006), and social attention (Valid=325.7 , Invalid=360.2; $F_{(1,15)}$=23.2, p<0.001). (See Table 4 for a complete list of means).

For accuracy measures a 3 x 2 x2 ANOVA with factors of attention type, visual field, and validity also revealed a significant main effect of validity (Valid=99.1%, Invalid=96.8%; $F_{(1,15)}$=16.8, p=0.001). Separate 2 x 2 ANOVAs with factors of visual field and validity for each type of attention separately revealed a significant effect of validity for voluntary attention (Valid=99.0%, Invalid=96.6%; $F_{(1, 15)}$=10.6, p=0.005), reflexive attention (Valid=99.2%, Invalid=96.7%; $F_{(1, 15)}$=10.8, p=0.005), and social attention (Valid=99.2% , Invalid=97.1%; $F_{(1,15)}$=10.4 p=0.006). (See Table 4 for a complete list of means).

ERP results

P1: Amplitude

For the amplitude of the P1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 47/47 and electrode 51/52) was conducted with a 20ms time window around the peak. The peak varied between each type of attention. A time range of 82-102ms was used for social attention, 80-100ms for voluntary attention, and 78-98ms for reflexive attention. This ANOVA revealed a significant main effect of attention type (Voluntary=1.22µv, Reflexive=0.36µv, Social=1.08µv; $F_{(2, 14)}$=19.39, p<0.001), as well as significant main effect of visual field (RVF=0.60µv, LVF=1.18µv; $F_{(1, 15)}$=12.47, p=0.003). There was a significant interaction between attention type and visual field (Voluntary RVF= 0.60µv, Voluntary LVF=1.84µv, Reflexive RVF= 0.09µv, Reflexive LVF=0.63µv, Social RVF= 1.10µv, Social LVF=1.05µv; $F_{(2, 14)}$=11.53. p<0.001). There was no significant main effect of validity (Valid=0.90µv, Invalid=0.87µv; $F_{(1, 15)}$=0.12, p=0.730) and no interaction between attention type and visual field ($F_{(2, 14)}$=0.38. p=0.685).). (See Figure 17 for plots of early attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed no significant main effect of validity (Valid=1.03µv, Invalid=1.13µv; $F_{(1, 15)}$=0.29, p=0.597). (See Figure 18 for plots and Figure 19 for topography of the P1 component for social attention). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of visual field (RVF=0.60µv, LVF=1.84µv; $F_{(1, 15)}$=17.44, p<0.001). There was no significant main effect of validity (Valid=1.26µv, Invalid=1.18µv; $F_{(1, 15)}$=0.38, p=0.549). (See Figure 20 for plots and Figure 21 for topography of the P1 component for voluntary attention). For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of visual field (RVF=0.09µv, LVF=0.63µv; $F_{(1, 15)}$=9.06, p=0.009). There was no significant main effect of validity (Valid=0.42µv, Invalid=0.30µv; $F_{(1, 15)}$=0.30, p=0.590). (See Figure 22 for plots and Figure 23 for topography of the P1 component for reflexive attention; See Appendix for complete ANOVA tables).

P1: Latency

For the latency of the P1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type, validity, visual field, and electrode revealed a significant main effect of visual field (RVF=86.7ms, LVF=93.4ms; $F_{(1, 15)}$=5.77, p=0.030), as well as a near significant main effect of electrode (E47/48=89.3ms, E51/52=90.9ms; $F_{(1, 15)}$=4.13, p=0.060. There is also a significant interaction between validity and visual field (Valid Right=89.3ms, Invalid Right=84.3, Valid Left=93.4, Invalid Left=93.4; $F_{(1, 15)}$=5.74, p=0.030). There was no significant effect of attention type (Voluntary=90.3ms, Reflexive=88.4ms, Social=91.5ms; $F_{(2, 14)}$=1.27, p=0.296) or validity (Valid=91.3ms, Invalid=88.9, $F_{(1, 15)}$=1.72, p=0.210).(See Figure 17 for plots of early attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a main effect of visual field (RVF=87.0ms, LVF=94.3ms; $F_{(1, 15)}$=18.05, p<0.001). There was no main effect of validity (Valid=90.2, Invalid=91.1; $F_{(1, 15)}$=0.39, p=0.544). (See Figure 18 for plots and Figure 19 for topography of the P1 component for social attention). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of visual field (RVF=87.5ms, LVF=93.4ms; $F_{(1, 15)}$=5.38, p=0.035), but no significant main effect of validity (Valid=90.3ms, Invalid=90.9ms; $F_{(1, 15)}$=0.38, p=0.549) or any other main effects or interactions. (See Figure 20 for plots and Figure 21 for topography of the P1 component for voluntary attention). For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant interaction between validity and visual field (Valid RVF=90.5ms, Valid LVF=86.0ms, Invalid RVF=80.3, Invalid LVF=87.3; $F_{(1, 15)}$=13.47, p=0.002). There was no significant main effect of validity (Valid=88.3ms, Invalid=83.8ms; $F_{(1, 15)}$=3.03, p=0.103). (See Figure 22 for plots and Figure 22 for topography of the P1 component for reflexive attention; See Appendix for complete ANOVA tables).

Late P1: Amplitude

Although the peak of the P1 showed no significant validity effect for reflexive cuing blocks, inspection of the reflexive waveforms suggest that there is a positive shift in the late phase of the P1. Recent ERP and neural modeling studies suggest that the late phase of the P1 that is actually generated from a area within the brain than the earlier peak of the P1 (Hopfinger and West, 2006; DiRusso et al., 2001; 2003; Martinez et al., 1999;2001). Therefore a 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode was conducted for the time range of 100-120ms for reflexive attention blocks. The amplitude of the late phase of the P1 component was significantly larger for valid trials than for invalid trials (Valid=0.32μv, Invalid=-0.54μv; $F_{(1, 15)}$=4.89, p=0.043). (See Figure 22 for the waveform and Figure 23 for the topography of the late phase of the P1 component; See Appendix for complete ANOVA tables).

N1: Amplitude

For the amplitude of the N1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 47/47 and electrode 89/90) revealed a significant main effect of validity (Valid= -0.90μv, Invalid= -1.22μv; $F_{(1, 15)}$=6.67, p=0.021), a significant main effect of electrode (E47/48= -0.95μv, E89/90= -1.17μv, $F_{(1, 15)}$=7.98, p=0.013), and a significant interaction between attention type and validity (Voluntary Valid= -0.98μv, Voluntary Invalid= -1.03μv, Reflexive Valid= -0.87μv, Reflexive Invalid = -1.81μv, Social Valid= -0.84μv, Social Invalid= -0.82μv; $F_{(1, 15)}$=11.56,

$p<0.001$). There is no significant main effect of attention type (Voluntary= -1.00µv, Reflexive= -1.34µv, Social= -0.83µv; $F_{(2, 14)}=2.35$, $p=0.113$).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}= 0.18$, $p=0.674$). An ANOVA with reflexive and social attention revealed a significant interaction between attention and validity ($F_{(1, 15)}= 12.21$, $p=0.003$). An ANOVA with reflexive and voluntary attention did show a significant interaction between attention and validity ($F_{(1, 15)}= 12.33$; $p<0.001$).

Separate 2 x 2 x 2 ANOVAs with factors of validity, visual field, and electrode for each type of attention separately show a significant effect of electrode (E47/48= -0.60µv, E89/90= -06µv; $F_{(1, 15)}=14.34$, p=0.002), but no effect of validity (Valid= -0.84, Invalid= -0.82; $F_{(1, 15)}=0.03$, $p=0.871$) for social attention. (See Figure 18 for the waveform and Figure 19 for the topography of the N1 component for social attention). For voluntary attention there was no significant effect of validity for voluntary attention blocks (Valid=-0.98µv, Invalid=-1.03µv; $F_{(1, 15)}=0.14$, $p=0.715$), but there was a trend towards a significant interaction between validity and electrode (Valid E47/48= -0.92µv, Valid E89/90= -1.03µv, Invalid E47/48= -0.92µv, Invalid E89/90= -1.14µv; $F_{(1, 15)}=4.39$, $p=0.054$). (See Figure 20 for the waveform and Figure 21 for the topography of the N1 component for voluntary attention). For reflexive attention blocks there was a significant validity effect (Valid=-0.87µv, Invalid= -1.81µv; $F_{(1, 15)}=19.18$, $p<0.001$) and no other significant effects. (See Figure 22 for the waveform and Figure 23 for the topography of the N1 component for reflexive attention; See Appendix for complete ANOVA tables).

N1:Latency

For the latency of the N1 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type, validity, visual field, and electrode revealed a significant main effect of attention (Voluntary=139.4ms, Reflexive=150.4ms, Social=155.2ms; $F_{(2, 14)}$=17.85, p<0.001), and a significant interaction between attention type and validity (Voluntary Valid= 138.2ms, Voluntary Invalid=141.2ms, Reflexive Valid= 156.7ms, Reflexive Invalid= 144.2ms, Social Valid= 154.8ms, Social Invalid= 155.6ms; $F_{(2, 14)}$=3.68, p=0.037), but no main effect of validity (Valid=149.9ms, Invalid=147.0ms; $F_{(1, 15)}$=0.79, p=0.387).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.31, p=0.589). An ANOVA with reflexive and social attention similarly revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 2.74, p=0.119). An ANOVA with reflexive and voluntary attention did show a significant interaction between attention and validity ($F_{(1, 15)}$= 4.77; p=0.045).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a main effect of electrode (E47/48= 154.1ms, E89/90=152.4ms; $F_{(1, 15)}$=7.82, p=0.014). There was no main effect of validity (Valid=153.3ms, Invalid=153.2ms; $F_{(1, 15)}$=0.02, p=0.882). (See Figure 18 for the waveform and Figure 19 for the topography of the N1 component for social attention). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant interaction between validity and visual field (Valid RVF=138.0ms, Valid LVF=139.5ms, Invalid RVF=137.3ms, Invalid LVF=142.3ms; $F_{(1, 15)}$=4.68, p=0.047), but no main effect of validity (Valid= 138.8, Invalid= 139.8; $F_{(1, 15)}$=2.35, p=0.146). (See Figure 20 for the waveform and Figure 21 for the topography of the N1 component for voluntary attention For reflexive blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of electrode (E47/48=153.2ms, E89/90=151.5ms; $F_{(1, 15)}$=18.26, p<0.001). There was no significant main effect of validity (Valid=154.6ms, Invalid=150.1ms; $F_{(1, 15)}$=3.0, p=0.104). (See Figure 22 for the waveform and Figure 23 for the topography of the N1 component for reflexive attention; See Appendix for complete ANOVA tables).

P2 Amplitude

Since the P2 component was elicited in Experiment 2 and showed validity differences, this component was explored in this experiment as well. For the amplitude of the P2 ERP component, a 3 x 2 x 2 x 3 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 82 and electrode 83) was conducted with a 20ms time window around the peak. The peak varied between each type of attention and validity. A time range of 190-210ms was used for valid trials with social attention, 195-215ms for invalid trails with social attention, 170-190ms for valid trials with voluntary attention, 190-210ms for invalid trials with voluntary attention, 170-190ms for valid trials on reflexive attention, and 170-190ms for invalid trials with reflexive attention.

The ANOVA revealed a significant main effect of attention type (Social=1.63μv, Voluntary=3.29μv, Reflexive=1.13μv; $F_{(2, 14)}$=16.96, p<0.001), and a significant main effect of validity (Valid=2.36μv, Invalid=1.67μv; $F_{(1, 15)}$=7.11, p=0.018. (See Figure 24 for plots of late attention effects).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode showed a significant main effect of validity (Valid=1.87μv, Invalid=1.17μv; $F_{(1, 15)}$=5.59, p=0.032). (See Figure 25 for plots and Figure 26 for topography of the P2 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of validity (Valid=3.86μv, Invalid=2.71μv; $F_{(1, 15)}$=4.98, p=0.041). (See Figure 27 for plots and Figure 28 for topography of the P2 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with the same factors revealed no significant effect of validity (Valid=1.34μv, Invalid=0.91μv; $F_{(1, 15)}$=2.50, p=0.134). (See Figure 29 for plots and Figure 30 for topography of the P2 component for reflexive attention blocks; See Appendix for complete ANOVA tables).

P300 Amplitude

For the amplitude of the P3 ERP component, a 3 x 2 x 2 x 2 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 83 and electrode 84) revealed a significant main effect of attention type (Voluntary=3.62μv, Reflexive=2.18μv, Social=2.54μv; $F_{(2, 14)}$=16.99, p<0.001), as well as significant interaction between attention type and validity (Voluntary Valid=3.29μv, Voluntary Invalid=3.96μv, Reflexive Valid=2.34μv, Reflexive Invalid=2.02μv, Social Valid=2.23μv, Social Invalid=2.86μv; $F_{(2, 14)}$=4.23, p=0.024), and an interaction between attention type and electrode (Voluntary

E83=3.61μv, Voluntary E84=3.64μv, Reflexive E83=2.02μv, Reflexive E84=2.33μv, Social E83=2.44μv, Social E84=2.64μv; $F_{(2, 14)}$=3.84, p=0.033).

Separate ANOVAs with two levels of attention type were conducted to explore which types of attention specifically were interacting with validity. An ANOVA with voluntary and social attention revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 0.57, p=0.463). An ANOVA with reflexive and social attention similarly revealed no significant interaction between attention and validity ($F_{(1, 15)}$= 3.80, p=0.070). An ANOVA with reflexive and voluntary attention did show a significant interaction between attention and validity ($F_{(1, 15)}$= 6.31; p=0.024).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant main effect of validity (Valid=2.23μv, Invalid=2.84μv; $F_{(1, 15)}$=14.56, p=0.002). (See Figure 25 for plots and Figure 26 for topography of the P300 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant effect of validity (Valid=3.34μv, Invalid=4.25μv; $F_{(1, 15)}$=6.30, p=0.024). (See Figure 27 for plots and Figure 28 for topography of the P300 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA no significant main effect of validity (Valid=2.50μv, Invalid=2.05μv; $F_{(1, 15)}$=2.52, p=0.134). (See Figure 29 for plots and Figure 30 for topography of the P300 component for reflection attention blocks; See Appendix for complete ANOVA tables).

N400 Amplitude

Like the P2 component, the effects observed in Experiment 2, led us to explore the N400 in this experiment as well. A 3 x 2 x 2 x 3 ANOVA with factors of attention type (voluntary, reflexive and social), validity (valid and invalid), visual field (right visual field and left visual field), and electrode (electrode 69, electrode 70 and electrode 85) was conducted with a 20ms time window around the peak. The peak varied between each type of attention and validity. A time range of 430-450ms was used for valid trials with social attention, 410-430ms for invalid trials with social attention, 400-420ms for valid trials with voluntary attention, 390-410ms for invalid trials with voluntary attention, 380-400ms for valid trials with reflexive attention, and 380-400ms for invalid trials with reflexive attention. The ANOVA revealed no significant main effects of attention type or validity and no interaction between the two. (See Figure 24 for a plot of late attention effects; See Appendix for complete ANOVA tables).

For social blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode showed no significant effect of validity (Valid=-1.11µv, Invalid=-1.17µv; $F_{(1, 15)}$=0.04, p=0.844). (See Figure 25 for plots and Figure 26 for topography of the N400 component for social attention blocks). For voluntary blocks a separate 2 x 2 x 2 ANOVA with factors of validity, visual field, and electrode revealed a significant larger amplitude N400 for valid trials then for invalid trials (Valid=-0.85µv, Invalid=-0.37µv; $F_{(1, 15)}$=4.84 p=0.044). (See Figure 27 for plots and Figure 28 for topography of the N400 component for voluntary attention blocks). For reflexive blocks a separate 2 x 2 x 2 ANOVA with the same factors revealed no significant main effect of validity (Valid=-0.90µv, Invalid=-1.24µv; $F_{(1, 15)}$=1.35, p=0.263). (See Figure 29 for plots and Figure 30 for topography of the N400 component for reflexive attention blocks; See Appendix for complete ANOVA tables).

Discussion

In the current experiment, all three types of attention were able to produce significant behavioral cuing effects. Even in this case where behavior was similar, the underlying processing of targets following each type of cue was different. At early stages of processing indexed by the P1 and N1 components, the social cues produced no significant validity effects, while the voluntary cues produced only a small latency effect at the N1 and the reflexive cues produced large differences in the amplitude of the late stages of the P1 and the N1.

Like in Experiment 2, the social gaze cues were able to produce significant behavioral cuing effects, but in the current study, there was no evidence of enhanced target processing exhibited in the early visual ERPs. There were no significant amplitude or latency differences in either the P1 or N1 ERP components. Again, it seems possible that a localization task is too simple to produce effects in these early visual processing components (e.g. Handy and Mangun, 2000; Vogel and Luck, 2000) especially at the short SOAs.

The voluntary cuing blocks in which participants were voluntarily directing their attention to the possible target locations, produced the normal and expected behavioral effect of shorter reaction times when the target appeared at the valid location compared the when it occurred at the opposite location. This suggests that participants were successfully shifting their attention to the probable target location following the color change of the fixation point. Like in Experiment 2 though, this validity effect was not exhibited in the amplitude of either the P1 or N1 ERP component. Again it seems possible that this lack of amplitude modulation could be due to the use of a localization task instead of either detection or discrimination task, as this is a main difference between the current study and most previous voluntary attention studies.

There was also no main effect of validity for the latency of the P1 or, unlike in Experiment 2, the N1 component. There was though, a significant interaction between validity and visual field for the latency of the N1 component. While there was no validity effect on N1 latency for right visual field targets, the N1 component for left visual field targets was speeded when the target was valid compared to when it was invalid.

The short SOA used in this experiment led to facilitation of target processing for the reflexively valid target location exhibited in reaction times. Interestingly the amplitude differences exhibited in the late stages of the P1 and the N1 component are in the opposite direction than those in Experiment 2, this suggests that while there was no behavioral evidence of IOR for reflexive attention in Experiment 2, IOR may have been beginning to occur at the early stages of visual processing. As well as amplitude difference in the present study, there were also latency effects for the P1 component in which the valid trials had a longer latency P1 than the invalid trials. It seems possible that this latency difference is due to the enhancement of the amplitude of the P1 component at the later stage of the P1 component. The extra enhancement that only occurs at the late stages of the P1 seems to be delaying the peak of the P1 for the valid trials. The emergence of latency effects which are not usually present in reflexive cuing paradigms once again raises the possibility that the latency effects seen in the current study, as well as those seen in the social gaze cuing studies conducted by Shuller and Rossion (2001, 2004, 2005), is due to the use of a localization task instead of the detection and discrimination tasks often used in reflexive and voluntary cuing paradigms. Previous studies have not reported latency shifts for P1 and N1 components, but with a localization, we see latency shifts with both voluntary and reflexive attention in certain situations.

An ANOVA including the factor of attention type revealed a significant effect of attention type on the amplitude of the P1 component in which the targets following voluntary cues produce the largest amplitude P1, than those following social cues and finally those following reflexive cues. This suggests that the different types of cues, while all leading to faster reaction times, affect overall target processing differently. This is also evident by the fact that there is a significant interaction between attention type and visual field for the P1 amplitude. There is a larger amplitude P1 component for left visual field targets following both reflexive and voluntary targets, but there is no visual field difference for targets following social gaze cues. By the level of processing indexed by the N1 component, there is also a main effect of attention type in which the latency of the N1 component is shortest for targets following voluntary cues and longest for targets following social cues, again suggesting that these cues are affecting target processing in varying ways regardless of whether the cue is valid or invalid.

The P2 component, like in Experiment 2 showed different effects and a different topography than the P300 component. Social and Voluntary attention both had an increased P2 component for valid trials compared to invalid trials while reflexive attention showed no significant effects. This again suggests the possibility that voluntary and social attention produce different alerting effects than reflexive attention, as the P2 has been suggested by some to evidence of general alerting from activity from the Reticular Activating System (e.g. Naatanen & Picton, 1987; Woods et al., 1993).

Similarly to the results of Experiment 2, the P300 component is larger for invalid trials for both voluntary and social attention. Further exploration of the distribution of this component again reveals that the invalid trials for the voluntary attention blocks have a more anterior distribution suggesting a separate neural generator. It is unclear why the invalid trials produce a larger P300 component for social attention, but it does replicate the findings of Schuller and Rossion (2001; 2005). It is possible that the social gaze cues produce such a strong cuing effect that an incongruent cue produces a oddball P3b response.

The N400 in this experiment was only showed a significant validity effect for voluntary attention, again this does not seem comparable to the N400 attention effect in which an out of place word at the end of a sentence produces a larger N400 component, as the valid targets are the targets that are most expected. This suggests that this late negative component may be reflecting a different process, such overlap from the P300 effect where invalid targets had a more positive amplitude than valid targets for voluntary attention blocks.

The results of Experiment 3 suggest that even in the case where each type of attention produces similar behavioral effects of reaction time and accuracy, there are different underlying neural correlates to these cuing effects. In this third experiment, the behavioral effects produced by social cues were not exhibited in the early levels of processing indexed by the P1 or N1 component, while both voluntary and reflexive attention showed modulation in the amplitude and/or latency of one or both of those components.

CHAPTER 7

GENERAL DISCUSSION

The current study provides us with a greater understanding of how social gaze orienting compares to reflexive and voluntary orienting. Previous research has concentrated on exploring whether voluntary and reflexive attention are separable systems or are just two different ways of controlling the same system. The discovery of the phenomenon of social gaze orienting leads to the question of where it fits within these two “classic” types of attentional orienting. It seems to share some properties of reflexive attention (it is engaged automatically) and voluntary attention (a central symbolic cue is used to produce it). It also, though, seems to be separate form both types in that it has a distinct social component to it.

Exploring the relationships between these different types of orienting by exploring ERPs of each within the same subjects, using similar stimuli, a similar task, and the same timing for each, allows us to conclude that social gaze cuing is distinct from reflexive attention. At the mid-length SOA (300-500ms), social attention and reflexive attention show different behavioral effects as well as dramatically different early visual processing at levels of processing indexed by the P1 and N1 EPR components. While the behavioral effects and early stages of visual processing suggest that voluntary and social attention are similar, the distributions of the higher-order P300 component suggest some underlying differences for invalid voluntary and social targets. The distribution of the P300 component for invalid voluntary trials resembles the distribution of the P3a component produced in a 3-stimulus oddball task in which novel stimuli (such a dark bark) is presented through out a discrimination task in which infrequent targets (such low pitch beeps) need to distinguished from frequent distracters (such as high pitch beeps). The similarity in the distribution suggests that the voluntary invalid trials are considered odd and novel, compared to the voluntary valid trials. This makes sense considering the invalid trials only occur 25% of the time.

The N400 component pointed to the greatest differences between the underlying neural processing of social attention and the other two classically defined types attention. A similar component is studied widely throughout the language literature. This language N400 is elicited when the last word of a sentence is unexpected and anomalous. In both experiments, the voluntary valid trials produced greater amplitude N400 component than voluntary invalid trials. This is counterintuitive when considering the language N400 component, as the valid trials would be most expected and would therefore be expected to have a smaller amplitude N400 component than the invalid trials. This suggests the possibility that it is indexing another process, not indexed by the language N400. It is also possible that the invalid N400 is being pulled positive by the overlapping late stages of the P300 component. Since, in Experiment 2, the N400 for social cues shows the opposite validity effect, it seems more likely that the increased amplitude for invalid trials around the timing of the N400 is indexing a separate process. In this case the language definition of the N400 component fits very well. The social gaze cue trial seems very comparable to a sentence, which could end in a word that makes sense (a congruent target) or an anomalous word (incongruent target). It seems possible that social gaze cue trials would be processed in a more sentential manner than voluntary attention trials, as that would be a more naturally occurring situation. The voluntary trials, more specifically may be produced in a more mechanical, less syntactic manner that does not produce the N400 component normally evoked in language studies.

The evidence from this component, along with the differences in behavior, early visual processing components, and the P300, suggest that social attention is not simply another mechanism of directing voluntary and/or reflexive attention, but is instead a separate mechanism that leads to distinct processing of a gazed at object.

It is not clear from the current data why a totally separate attentional system would have evolved for social gaze attention. Most of the functions and outcomes of social gaze attentional system would be similar to those of voluntary and reflexive attention (behaviorally all types lead to faster and more accurate responses). In Experiment 1c voluntary and social gaze attention were found to affect performance on a localization task and a discrimination task differentially. Specifically validity effects were seen for both tasks when voluntary attention cues were utilized, but only for the location task when social gaze cues directed attention. This raises the possibility that an attentional system cued by social stimuli developed separately because the information that a social gaze cue provides aids in different tasks than those aided by either reflexive or voluntary attention. While voluntary and reflexive attention can lead to information on features of a cued stimulus (such as in a discrimination task), the most important information received from a gaze cue in a non-verbal communication may be the location of where an interesting stimulus is (such as in a localization task).

The evidence that suggests that reflexive, voluntary, and social attention are separate attention systems needs to be considered in future explorations into attention and specifically deficits in attention. When exploring possible problems with attention within a group, it is important to consider these key differences and explore each type of attention separately. Specifically, certain clinical populations may exhibit marked differences in one of these systems of attention, but to make a general assumption that the overall attention performance is affected one may be missing strengths that the same group has with a separate system of attention.

Future Directions

These studies point to differences between social attention and the classically defined voluntary and reflexive attention at the neural level. It is important to recognize however, that some of the normal voluntary attention effects produced in previous ERP studies (such as increased amplitude of the P1 and N1 components) are not produced in the current study. Previous voluntary attention studies have used detection and/or discrimination tasks and some studies have found that easier tasks and lower visual loads produce less attentional modulation of the amplitude of the P1 and N1. Therefore, it seems that use of a localization task in the current study may make it more difficult to produce these amplitude effects. It is also interesting that latency effects for the early components were found as these effects are not normally seen for voluntary or social attention, but have been produced by the one group who has explored neural underpinnings of social gaze orienting (2001; 2004; 2005). These studies all used a localization task. The current findings of latency effects for each type of attention suggest that the localization task is more sensitive at picking up on these possible latency differences or that the three types of attentional orienting affect target processing differentially for different types of tasks. Therefore while this study produced interesting new data of voluntary and reflexive attention using a localization task, it is important for future studies to find a stimulus set in which the behavioral social gaze cuing effects can be elucidated with detection or discrimination tasks with which the attention effects on early visual processing are better understood.

The difference between these types of orienting can also be explored by finding out how they are differentially affected in autism, a group that has both general attention deficits and social deficits. Interestingly, while these deficits do exist, social gaze orienting is generally intact in autism (e.g. Kyllianen & Hietanen, 2004; Senju et al., 2004). There are however small differences, such as visual field differences, that suggest the underlying neural mechanisms of social attention, and possibility voluntary and reflexive attention, may not show the normal patterns. Exploration of these possible underlying deficits, and how they vary across the different types of attention, can provide a better understanding of how the different types of attention are separable.

Table 1: Means and Standard Deviations for Reaction Times in Experiment 1a and 1b.

SOA	Left Valid	Left Invalid	Right Valid	Right Invalid
Exp1a: Short	652.6 ms	644.6 ms	649.4 ms	641.0 ms
SD	(111.5)	(103.2)	(112.7)	(102.7)
Exp1a: Mid	639.0 ms	644.5 ms	616.3 ms	625.4 ms
SD	(121.3)	(111.7)	(106.8)	(102.6)
Exp1a: Long	631.2 ms	639.5 ms	628.2 ms	634.5 ms
SD	(115.3)	(130.6)	(114.5)	(129.5)
Exp1b: Short	325.3 ms	355.6 ms	329.9 ms	357.6 ms
SD	(55.3)	(61.0)	(66.3)	(72.6)
Exp1b: Mid	312.0 ms	343.1 ms	316.1 ms	334.1 ms
SD	(48.3)	(54.4)	(48.5)	(60.6)
Exp1b: Long	332.6 ms	337.9 ms	328.5 ms	339.4 ms
SD	(53.0)	(60.9)	(61.3)	(61.4)

Table 2: Means and Standard Deviations for Accuracy in Experiment 1a and 1b.

SOA	Left Valid	Left Invalid	Right Valid	Right Invalid
Exp1a: Short	89.0%	88.0	89.9%	91.8%
SD	(16.8)	(13.2)	(20.4)	(13.8)
Exp1a: Mid	92.5%	94.2%	94.2%	93.8%
SD	(7.3)	(6.2)	(4.6)	(8.7)
Exp1a: Long	90.9%	90.4%	96.2%	94.5%
SD	(9.5)	(10.3)	(4.1)	(7.6)
Exp1b: Short	100.0%	99.0%	99.7%	99.7%
SD	(0.0)	(1.5)	(0.9)	(0.9)
Exp1b: Mid	99.7%	99.7%	100.0%	99.5%
SD	(0.9)	(0.9)	(0.0)	(1.2)
Exp1b: Long	99.7%	99.7%	99.7%	99.7%
SD	(0.9)	(0.9)	(0.9)	(0.9)

Table 3: Means and Standard Deviations for Reaction Times and Accuracy in Exp 2.

SOA	Right Valid	Right Invalid	Left Valid	Left Invalid
RT: Social	307.4 ms	337.8 ms	294.2 ms	321.0 ms
SD	(43.9)	(60.0)	(38.3)	(50.0)
RT: Voluntary	288.7 ms	380.0 ms	315.2 ms	367.5 ms
SD	(51.1)	(70.9)	(81.8)	(72.9)
RT: Reflexive	320.9 ms	324.7 ms	315.8 ms	310.1 ms
SD	(51.3)	(61.4)	(42.3)	(43.8)
Acc: Social	98.3%	97.4%	99.1%	97.9%
SD	(2.8)	(4.4)	(1.3)	(2.1)
Acc: Voluntary	98.4%	92.2%	98.8%	94.6%
SD	(2.1)	(9.0)	(1.6)	(6.3)
Acc: Reflexive	97.7%	98.1%	98.8%	98.4%
SD	(4.0)	(2.8)	(1.5)	(2.7)

Table 4: Means and Standard Deviations for Reaction Times and Accuracy in Exp 3.

SOA	Right Valid	Right Invalid	Left Valid	Left Invalid
RT: Social	323.9 ms	364.2 ms	316.5 ms	357.8 ms
SD	(77.5)	(84.0)	(60.2)	(62.9)
RT: Voluntary	297.8 ms	400.5 ms	294.9 ms	398.5 ms
SD	(64.1)	(103.5)	(57.3)	(97.6)
RT: Reflexive	333.9 ms	368.4 ms	328.0 ms	360.5 ms
SD	(73.7)	(75.8)	(57.3)	(64.0)
Acc: Social	99.1%	96.9%	99.3%	97.5%
SD	(1.6)	(4.1)	(1.0)	(2.5)
Acc: Voluntary	98.8%	95.8%	99.3%	96.7%
SD	(1.8)	(5.9)	(0.9)	(3.6)
Acc: Reflexive	98.9%	95.5%	99.3%	96.6%
SD	(4.0)	(2.8)	(1.5)	(2.7)

Figure 1. An example of the stimuli used in Experiment 1a of the Current Study.

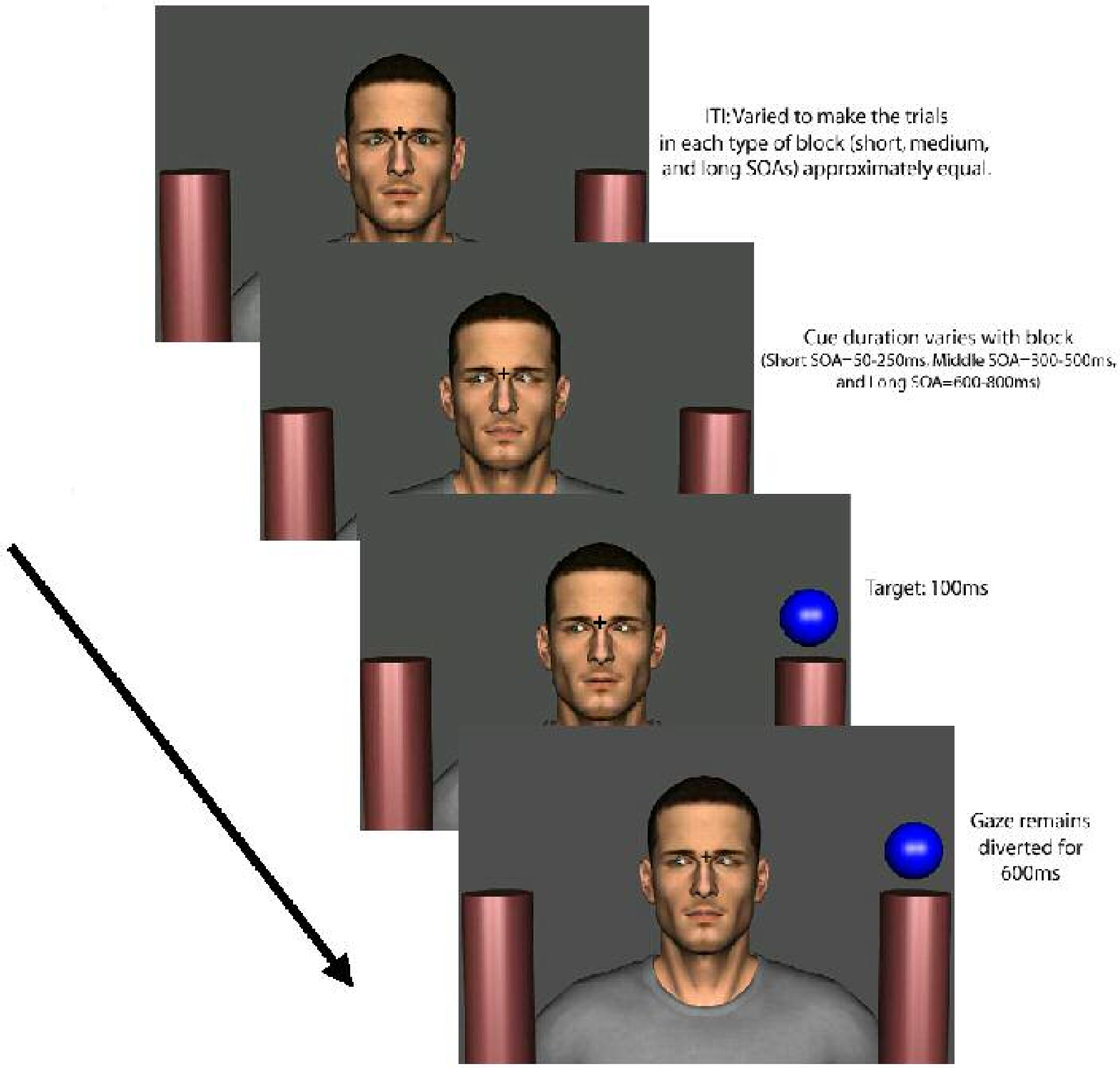

Figure 2a. An example the voluntary cue used in Experiments 1c, 2, and 3.

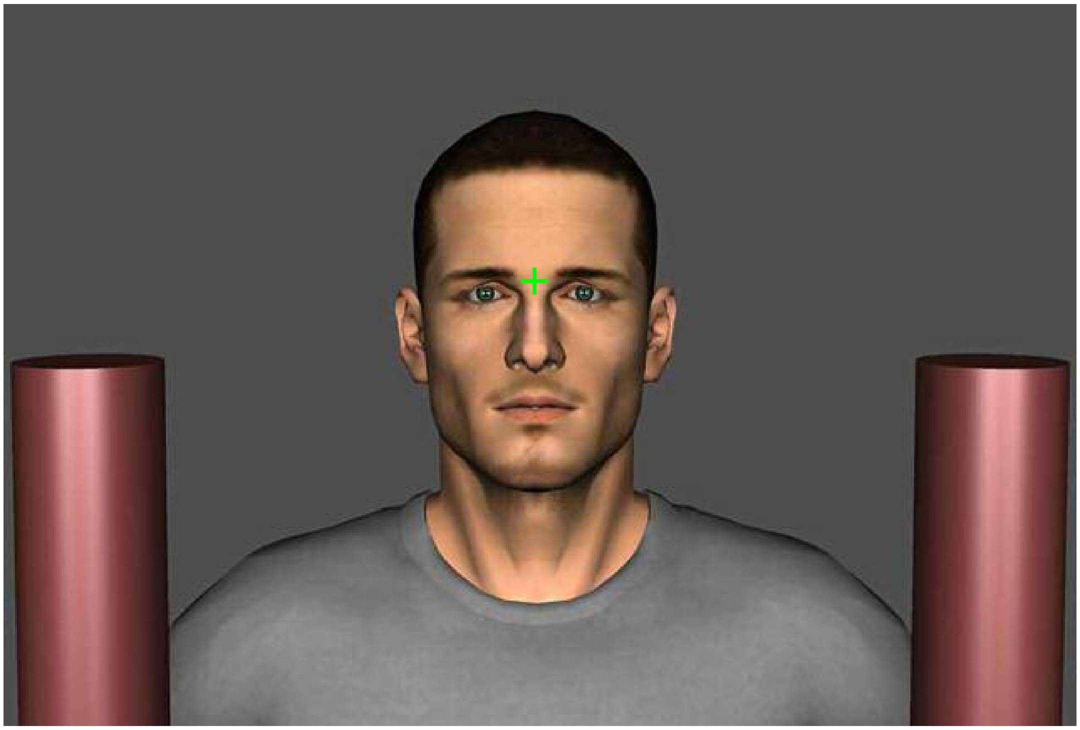

Figure 2b. An example the reflexive cue used in Experiments 2 and 3.

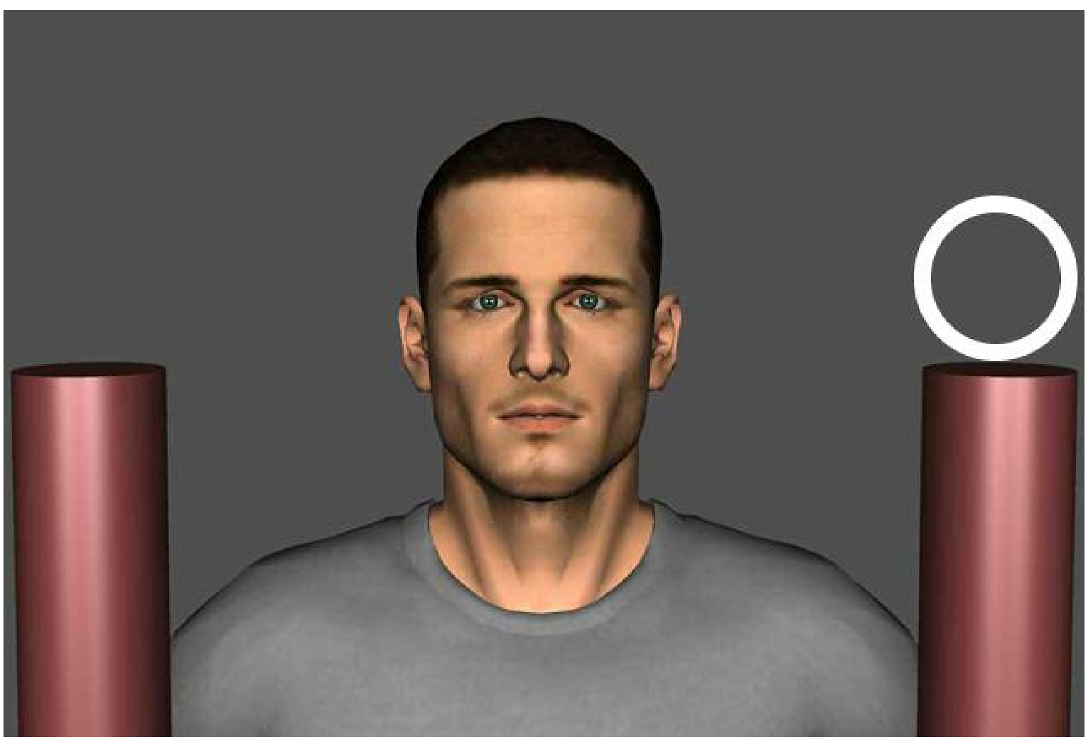

Figure 3. Experiment 2. Lateral electrodes showing the validity effect for social, voluntary and reflexive attention.

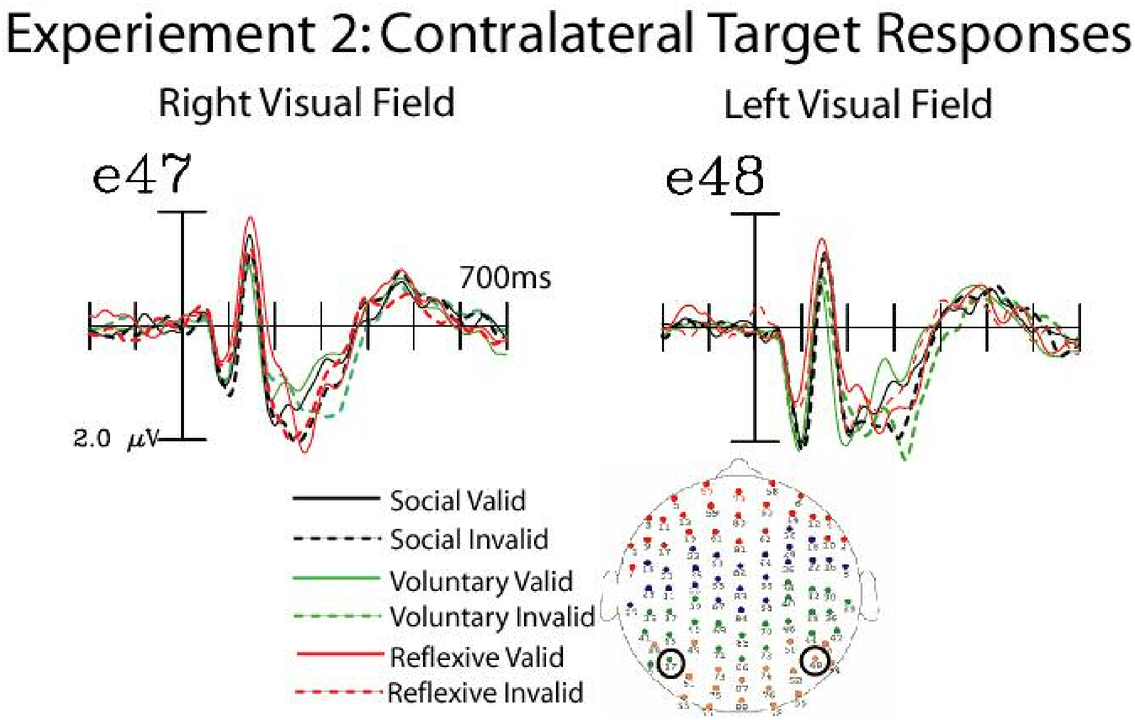

Figure 4. Experiment 2: ERP plots of lateral electrodes showing early visual components for Social attention blocks.

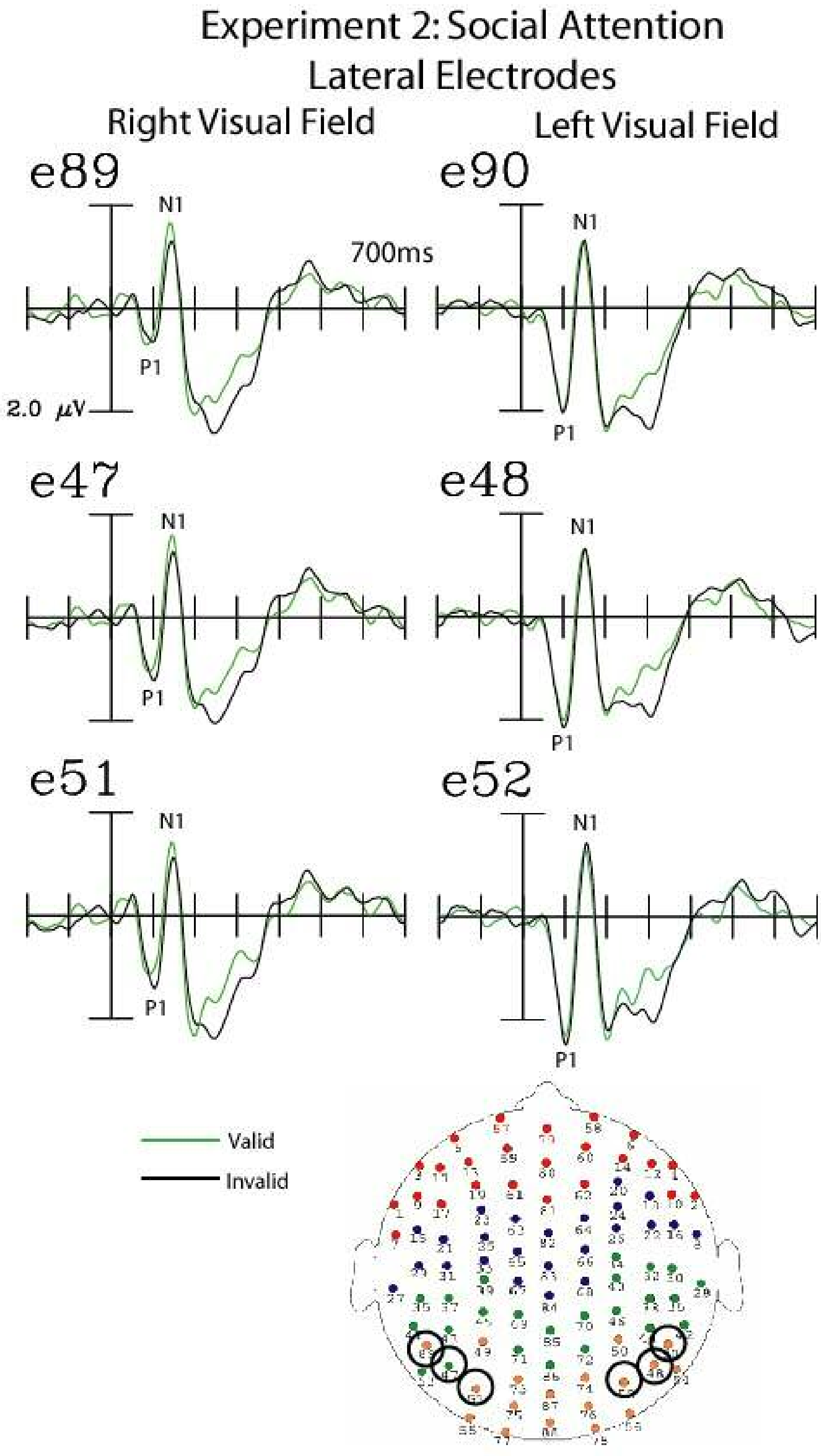

Figure 5. Experiment 2: Topographic maps of the P1 and N1 component for Social attention blocks.

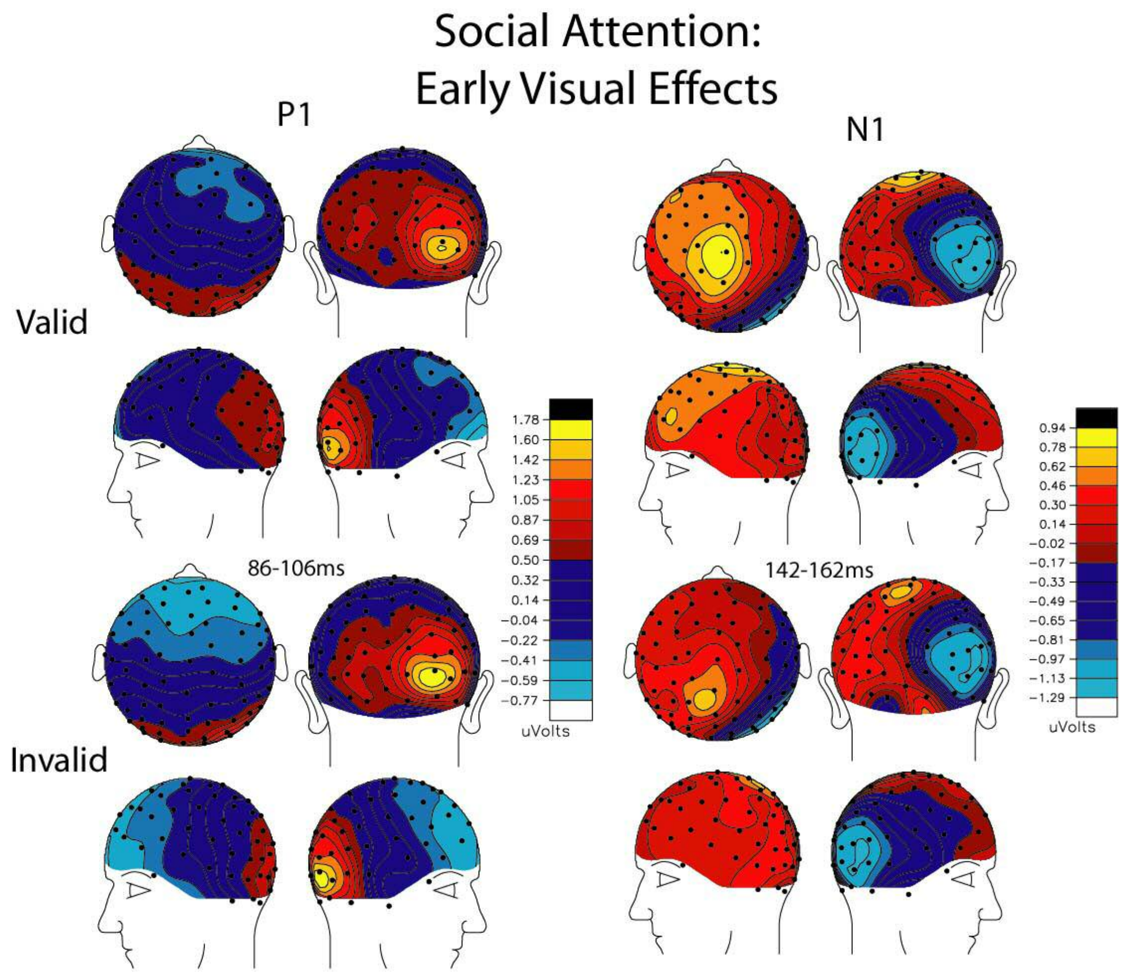

Figure 6. Experiment 2: ERP plots of lateral electrodes showing early visual components for Voluntary attention blocks.

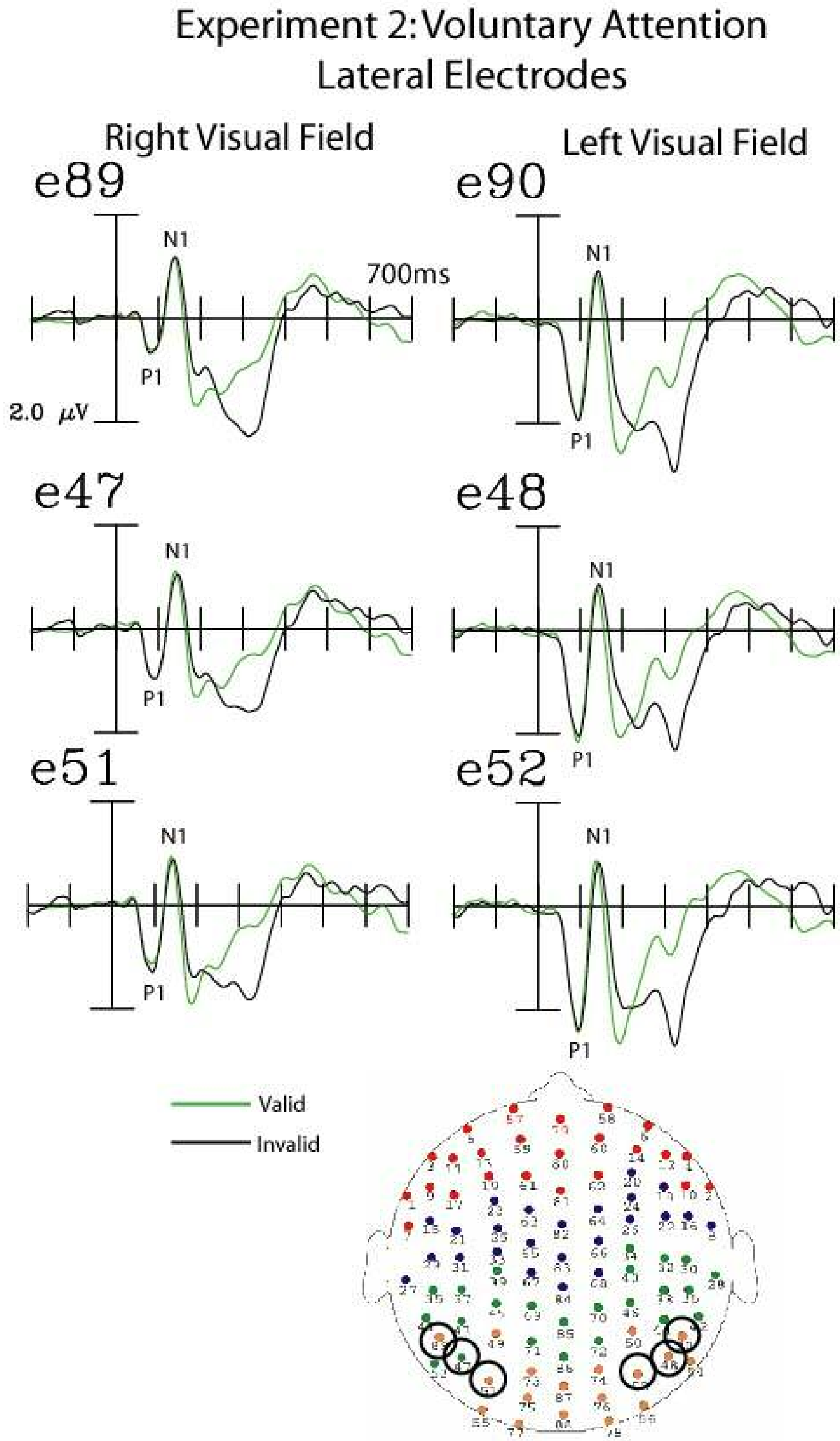

Figure 7. Experiment 2: Topographic maps of the P1 and N1 component for Voluntary attention blocks.

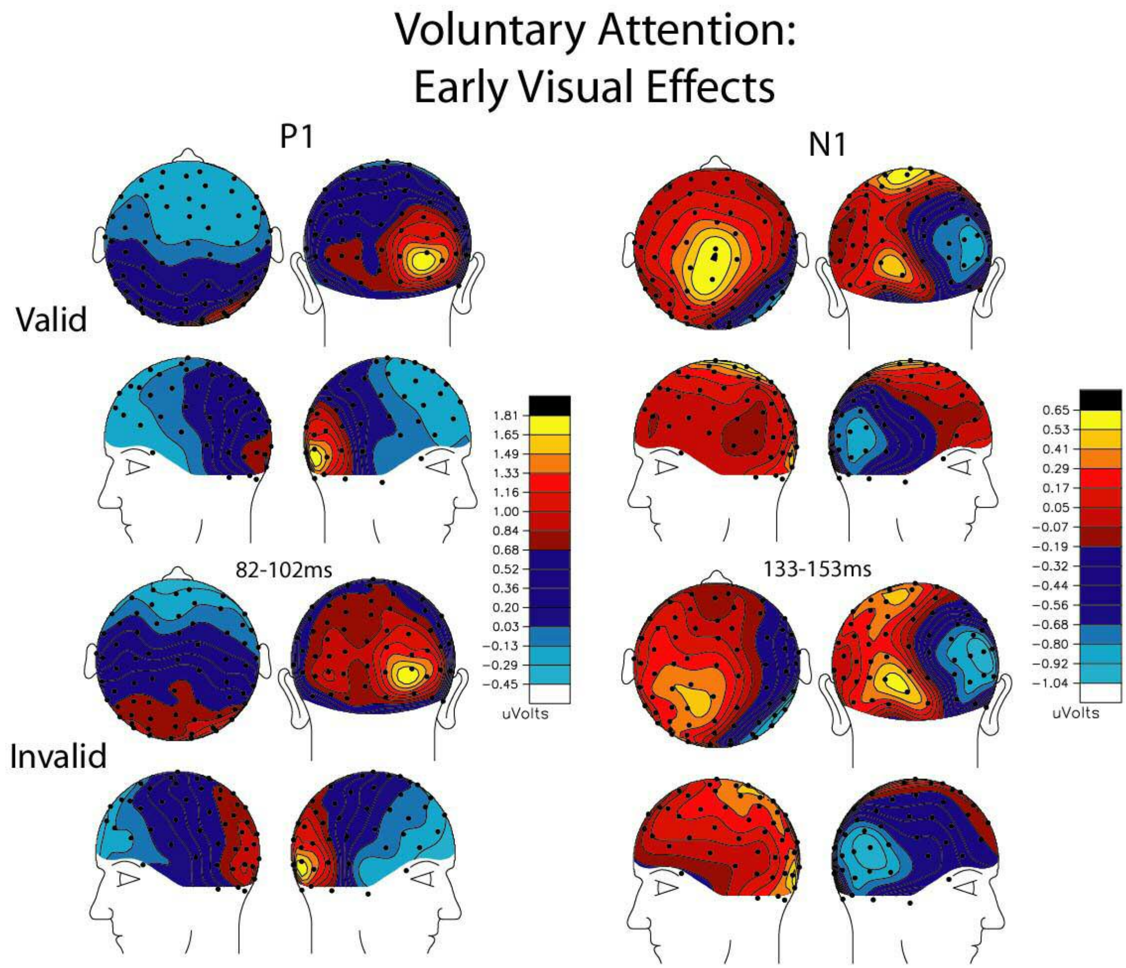

Figure 8. Experiment 2: ERP plots of lateral electrodes showing early visual components for Reflexive attention blocks

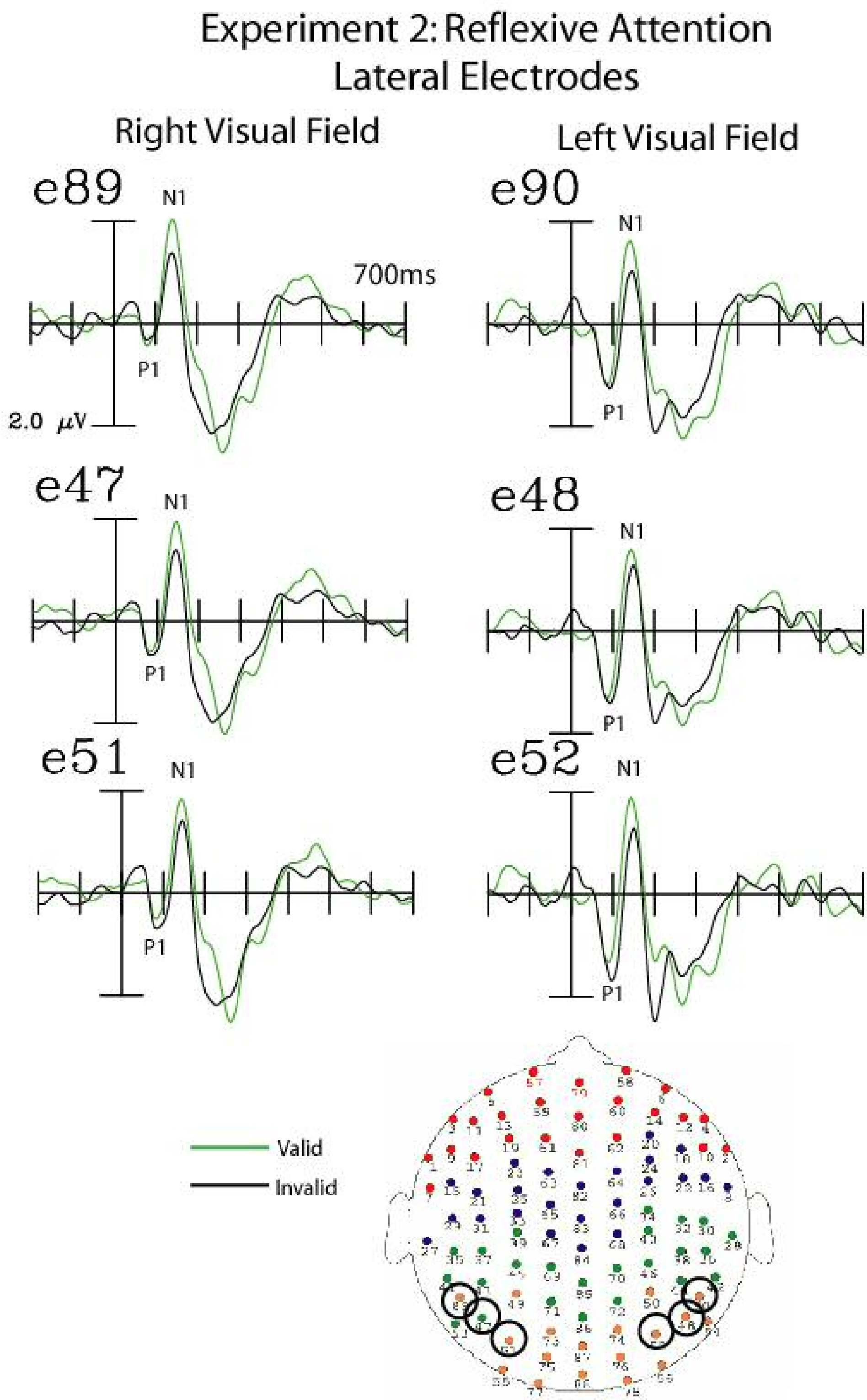

Figure 9. Experiment 2: Topographic maps of the P1 and N1 component for Reflexive attention blocks

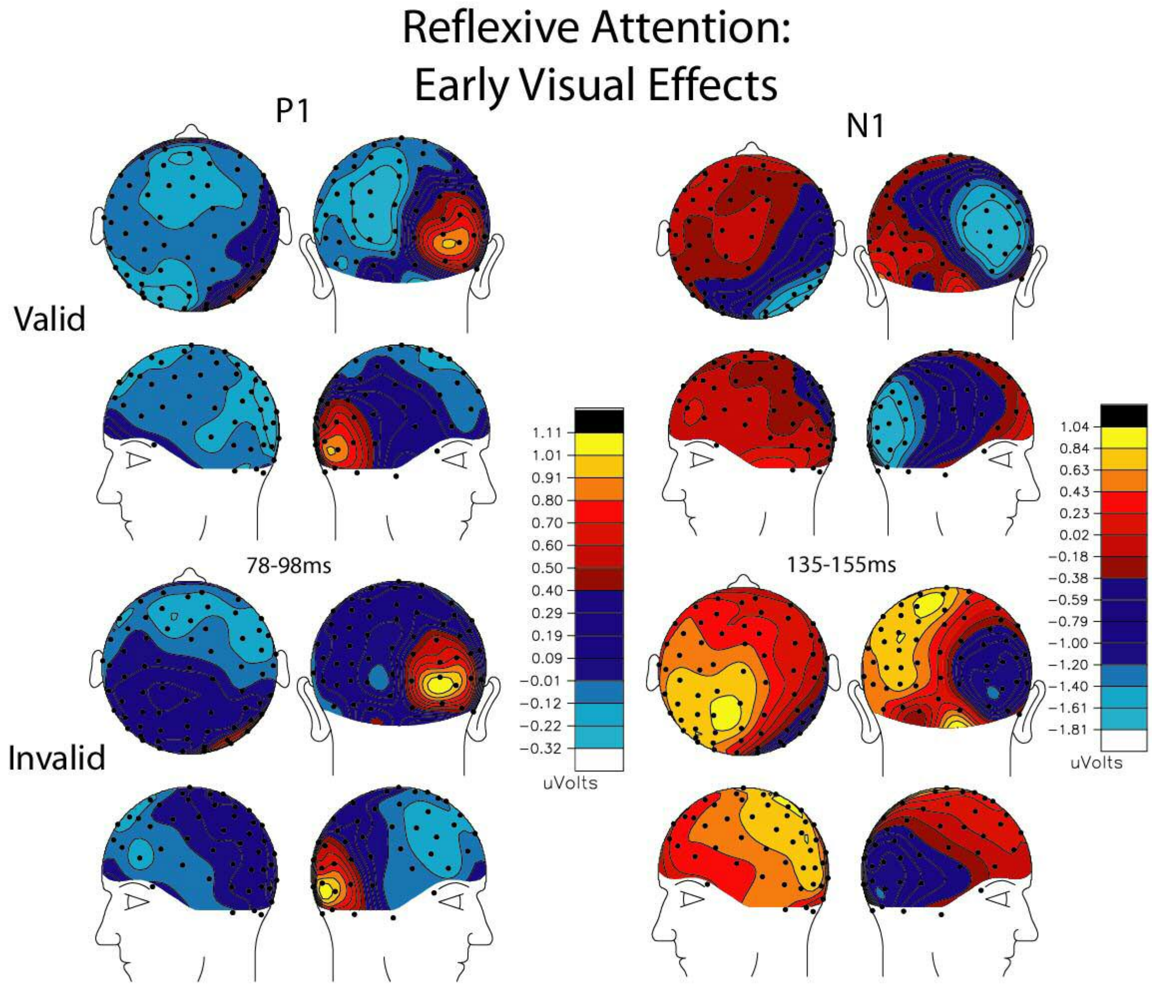

Figure 10. . Experiment 2. A medial electrode showing validity effects of social, voluntary, and reflexive attention.

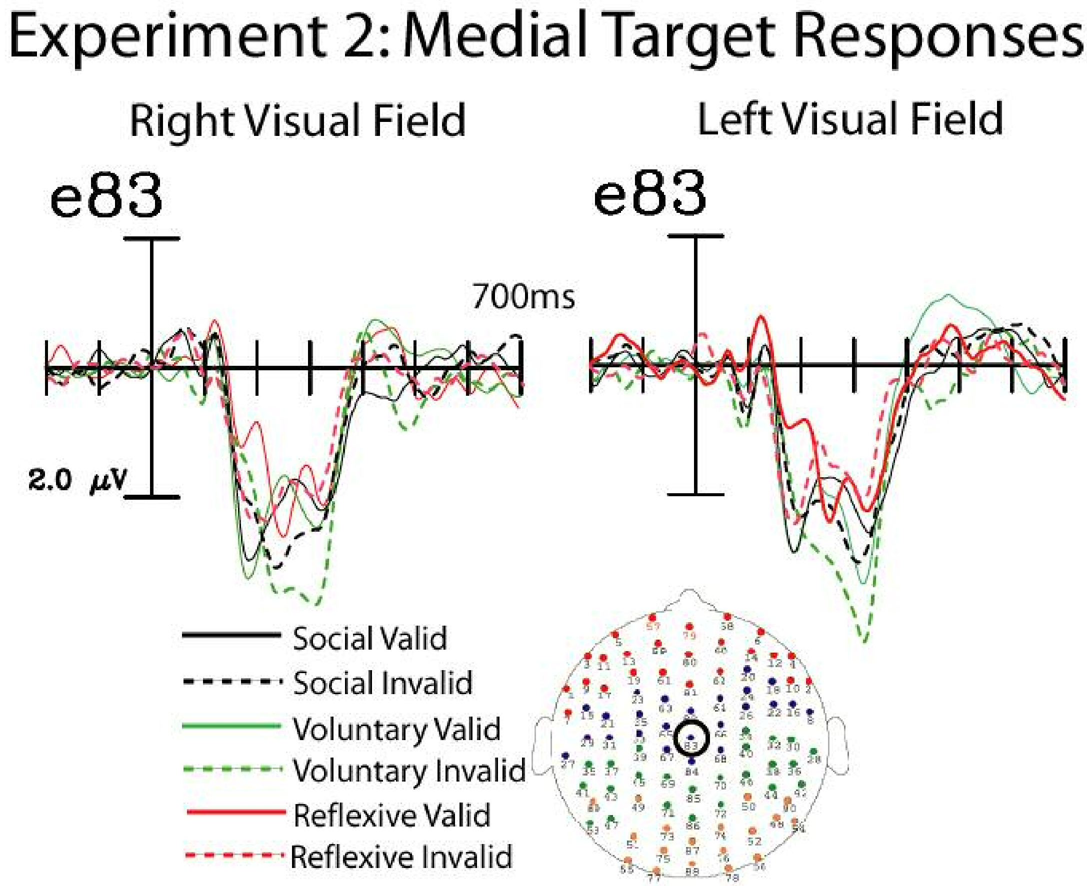

Figure 11. Experiment 2: ERP plots of lateral electrodes showing later processing components for Social attention blocks

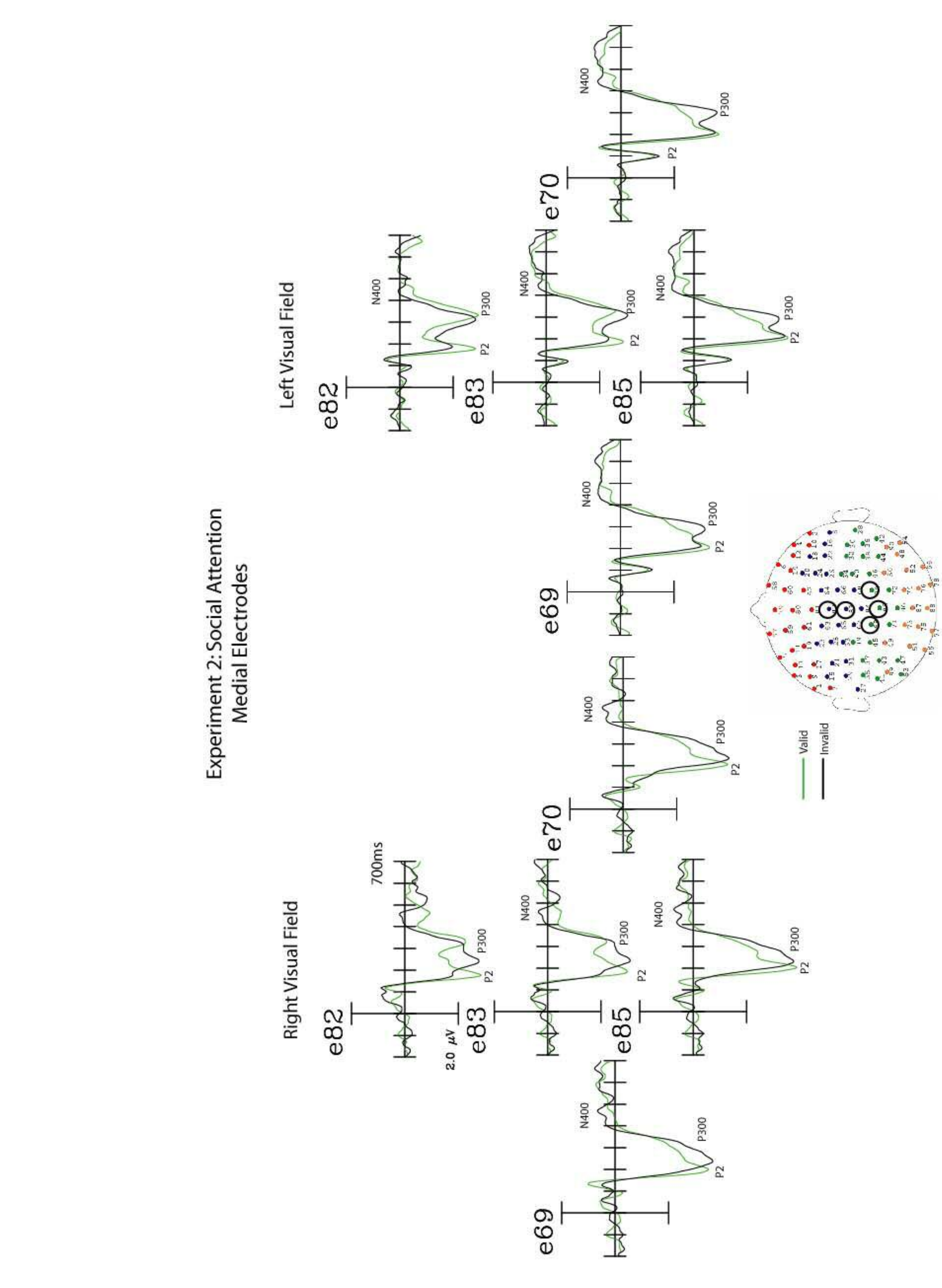

Figure12. Experiment 2: Topographic maps of the P2, P300 and N400 components for Social attention blocks.

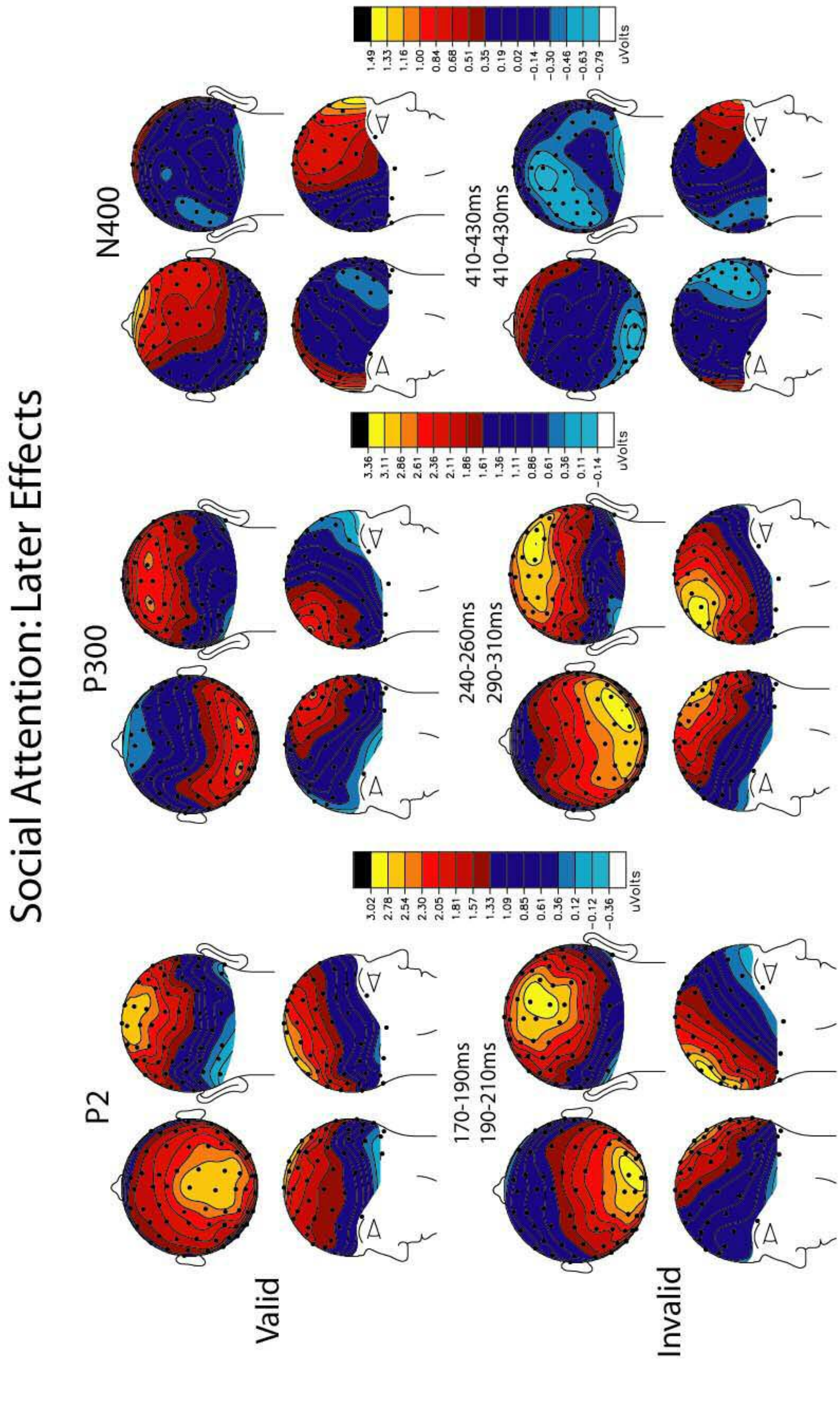

Figure13. Experiment 2: ERP plots of medial electrodes showing later processing components for Voluntary attention blocks

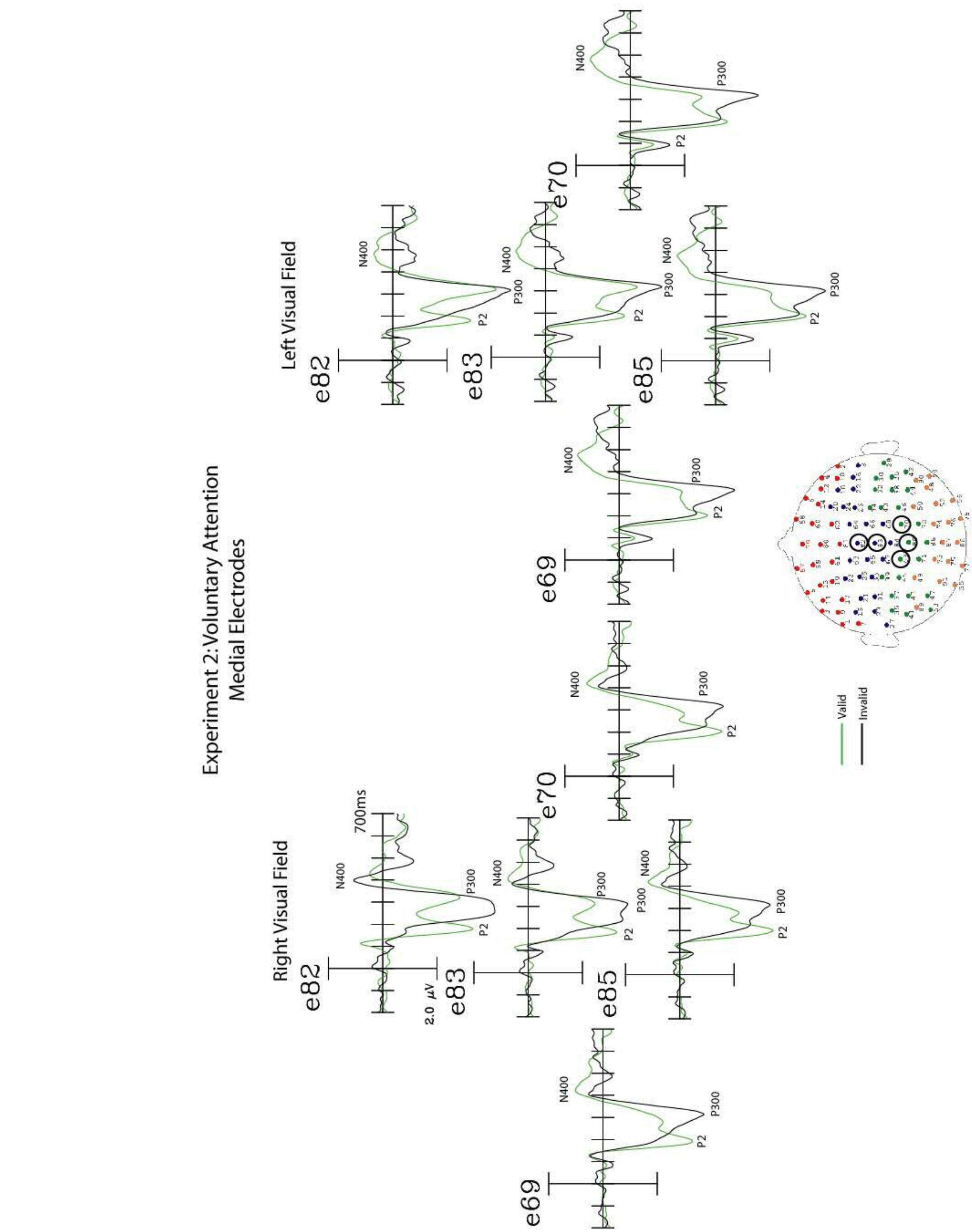

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Figure14. Experiment 2: Topographic maps of the P2, P300 and N400 components for Voluntary attention blocks.

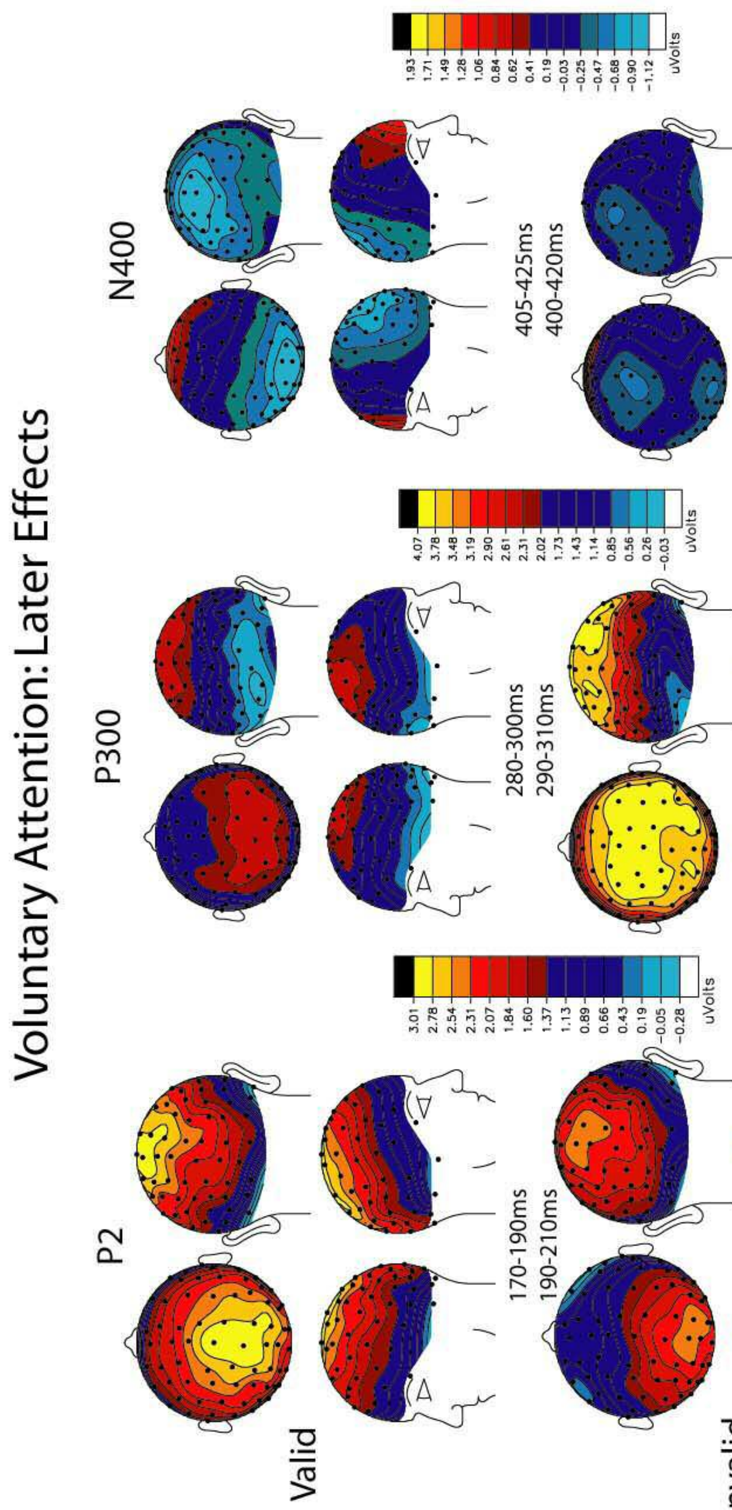


Figure15. Experiment 2: ERP plots of medial electrodes showing later processing components for Reflexive attention blocks.

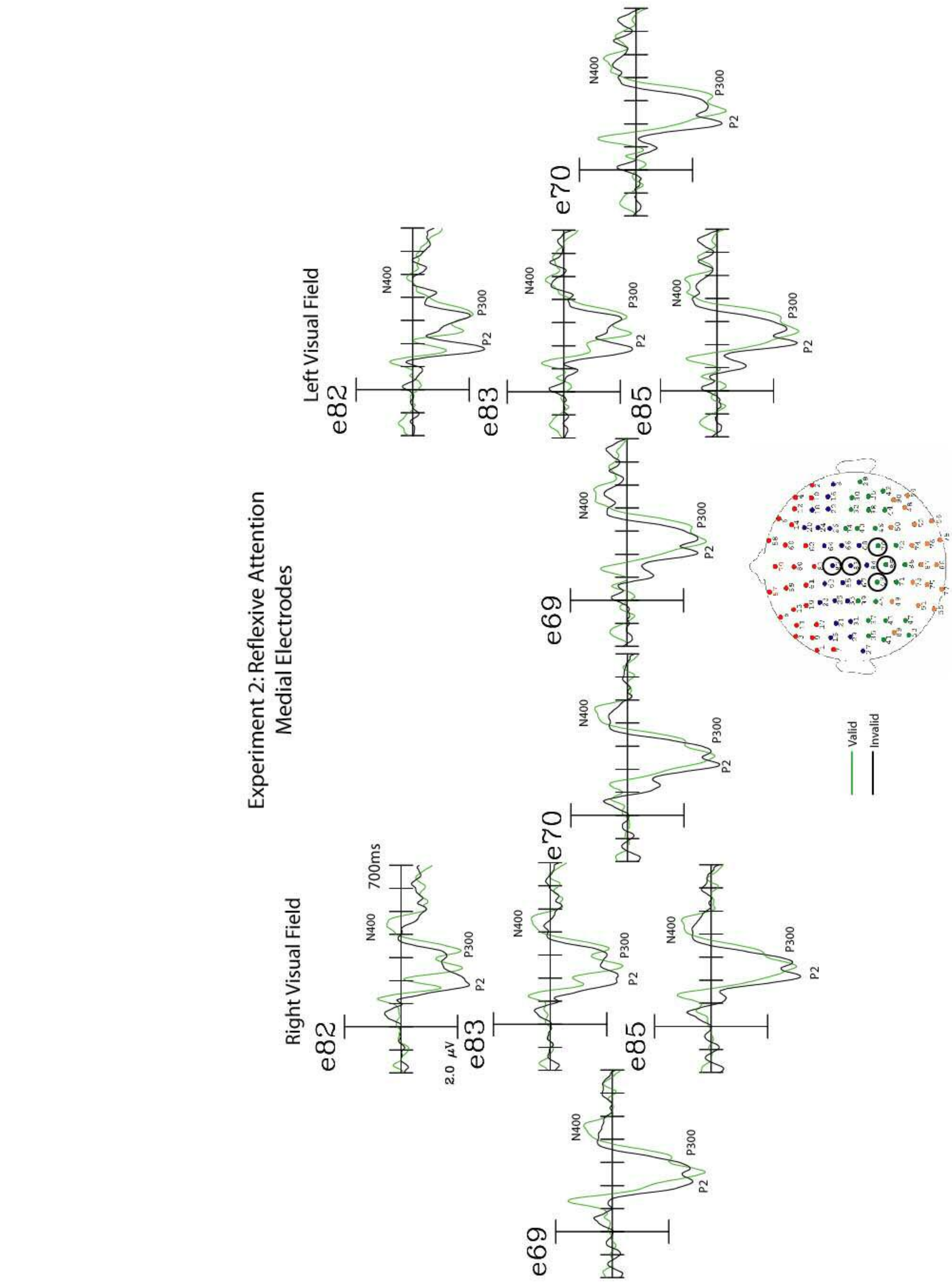


Figure16. Experiment 2: Topographic maps of the P2, P300 and N400 components for Reflexive attention blocks.

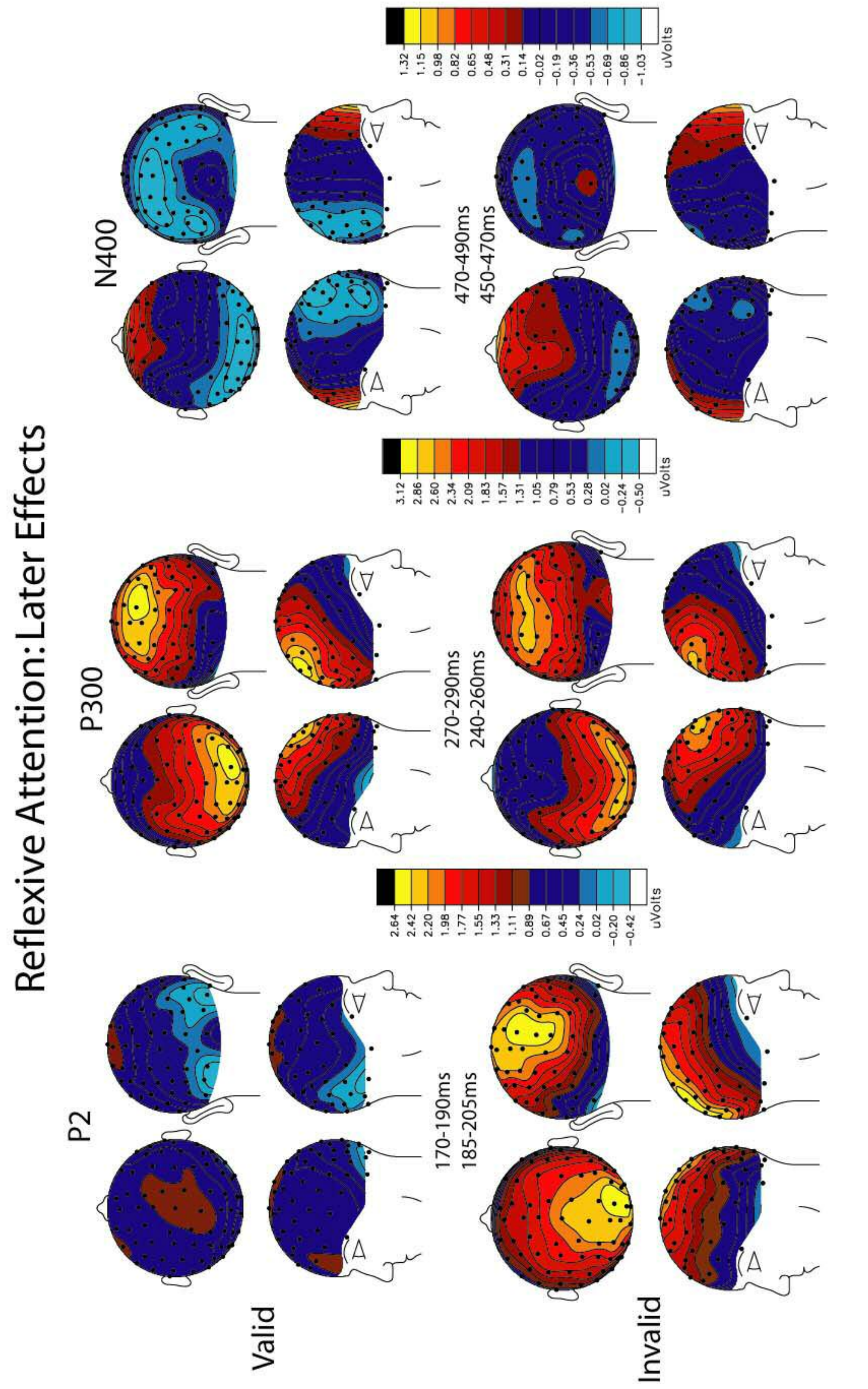


Figure 17. Experiment 3. Lateral electrodes showing the validity effect for social, voluntary and reflexive attention.

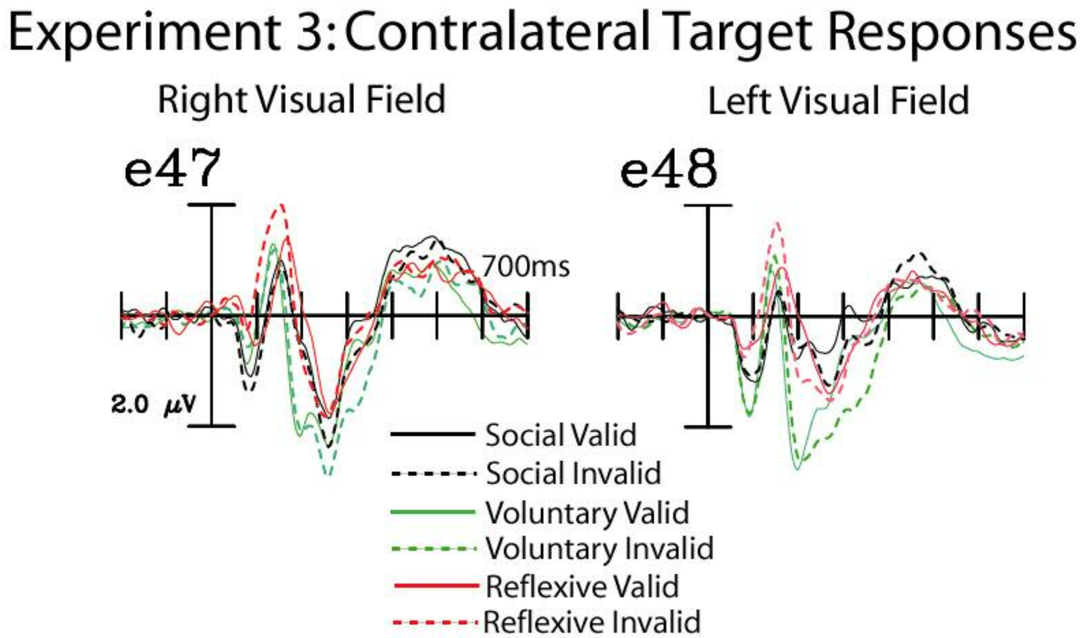


Figure 18. Experiment 3: ERP plots of lateral electrodes showing early visual processing components for Social attention blocks.

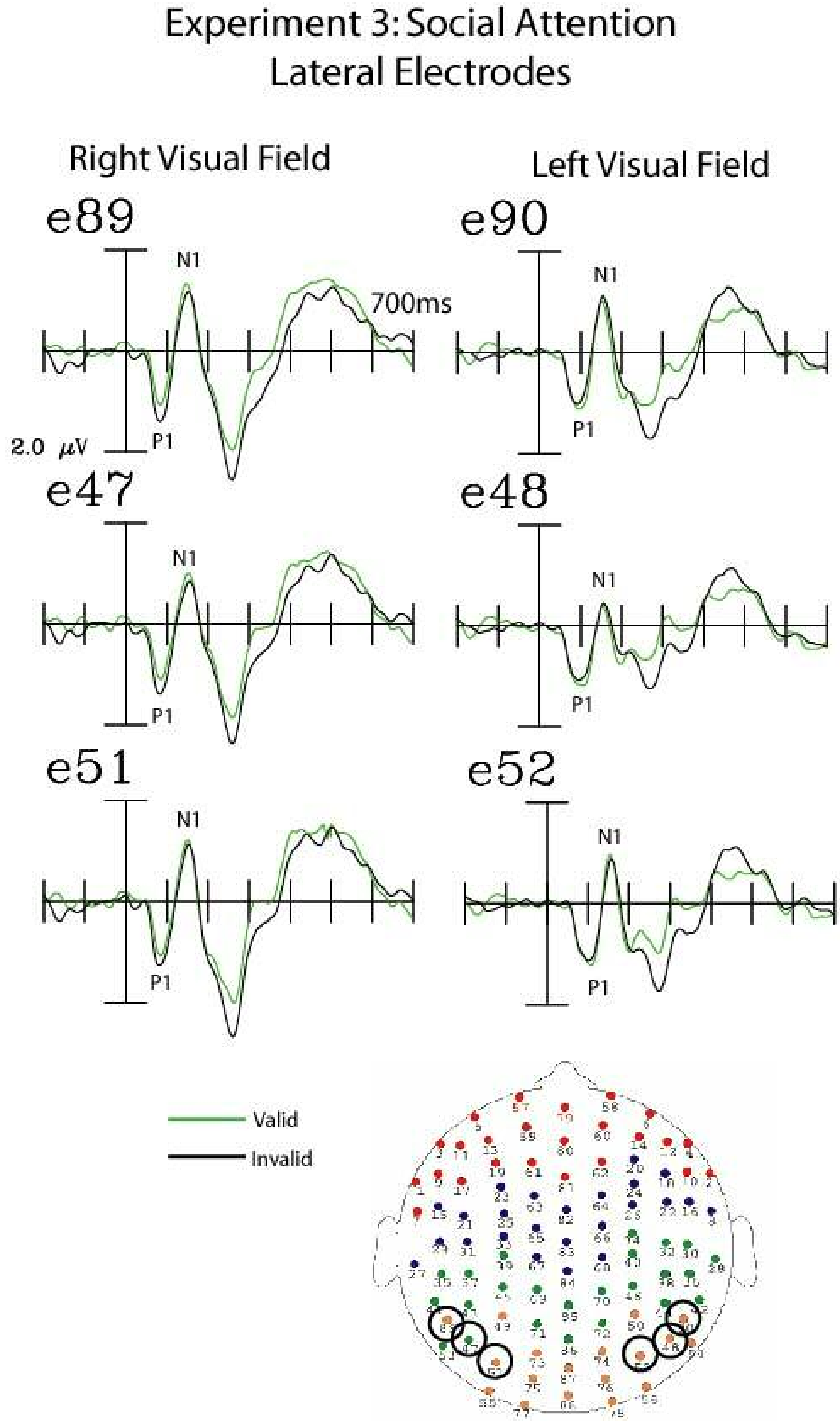


Figure19. Experiment 3: Topographic maps of the P1 and N1 components for Social attention blocks.

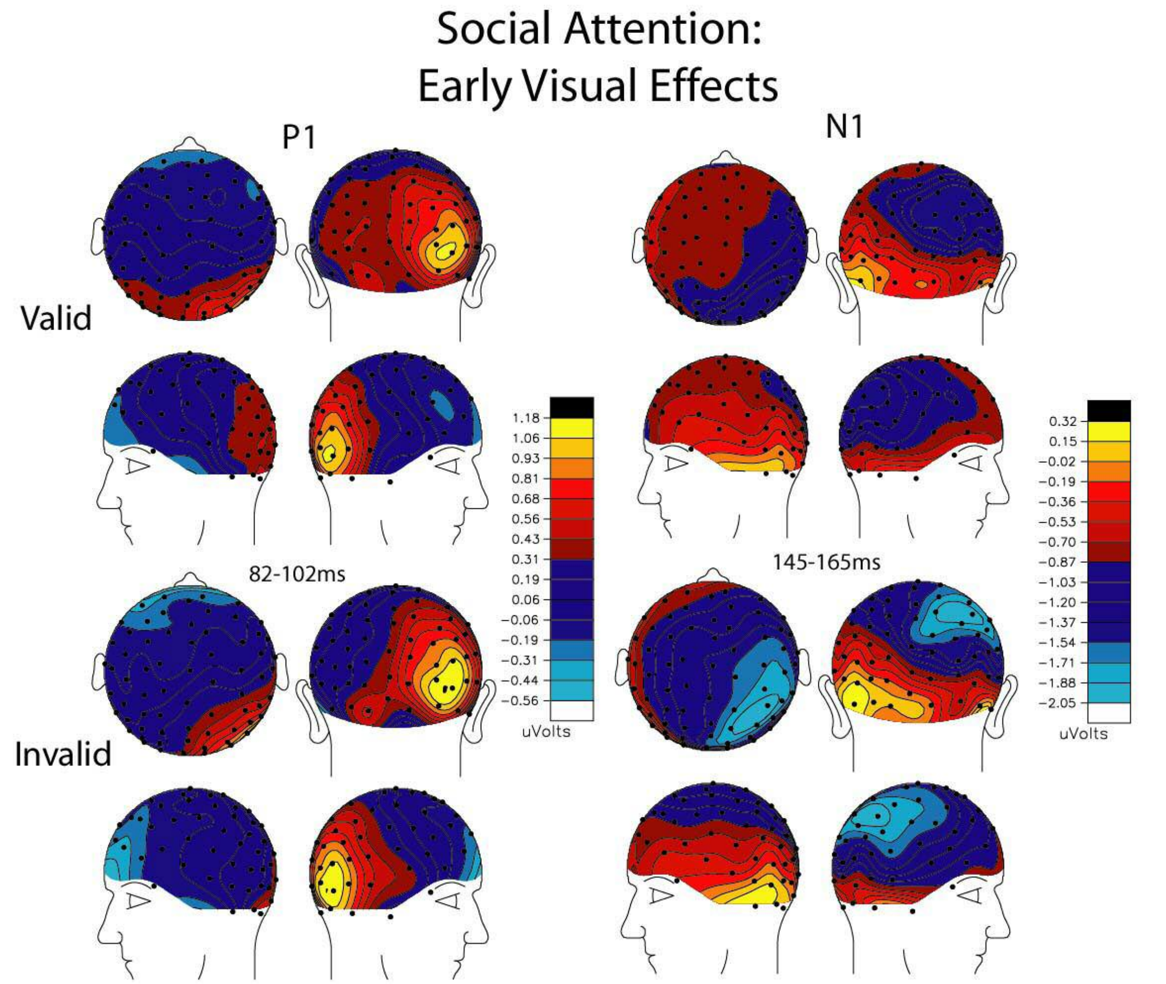


Figure 20. Experiment 3: ERP plots of lateral electrodes showing early visual processing components for Voluntary attention blocks.

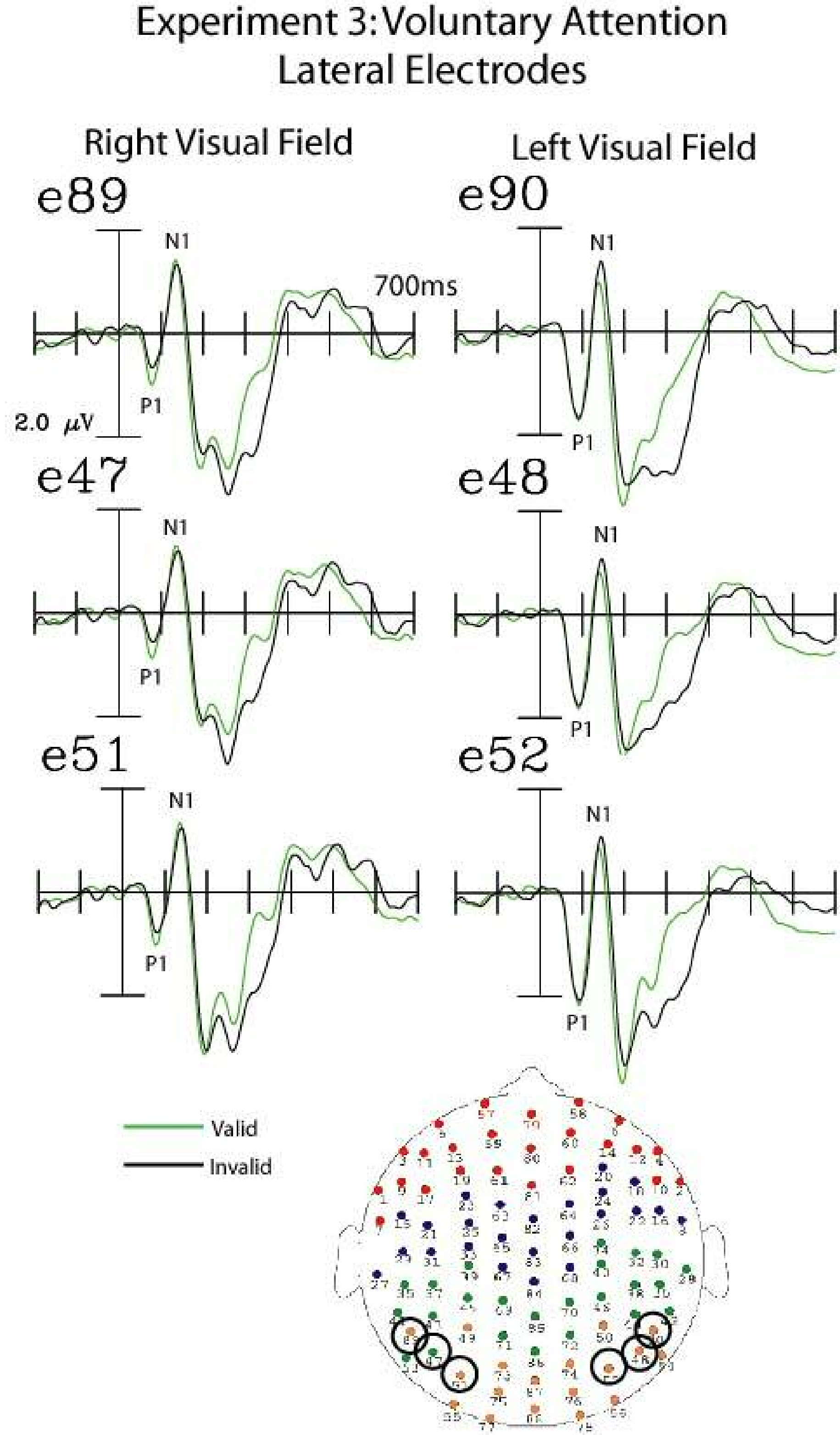


Figure 21. Experiment 3: Topographic maps of the P1 and N1 components for Voluntary attention blocks.

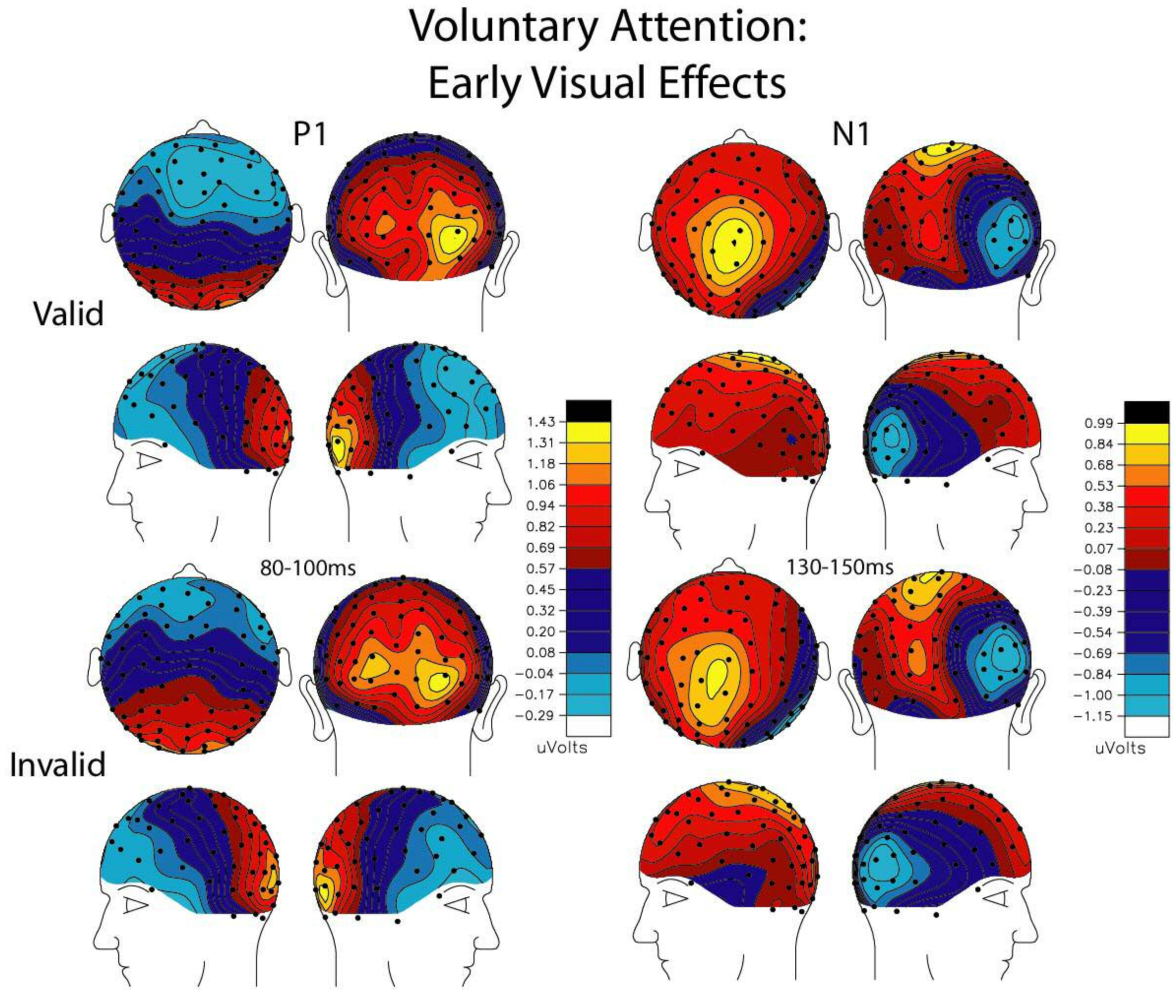


Figure 22. Experiment 3: ERP plots of lateral electrodes showing early visual processing components for Reflexive attention blocks.

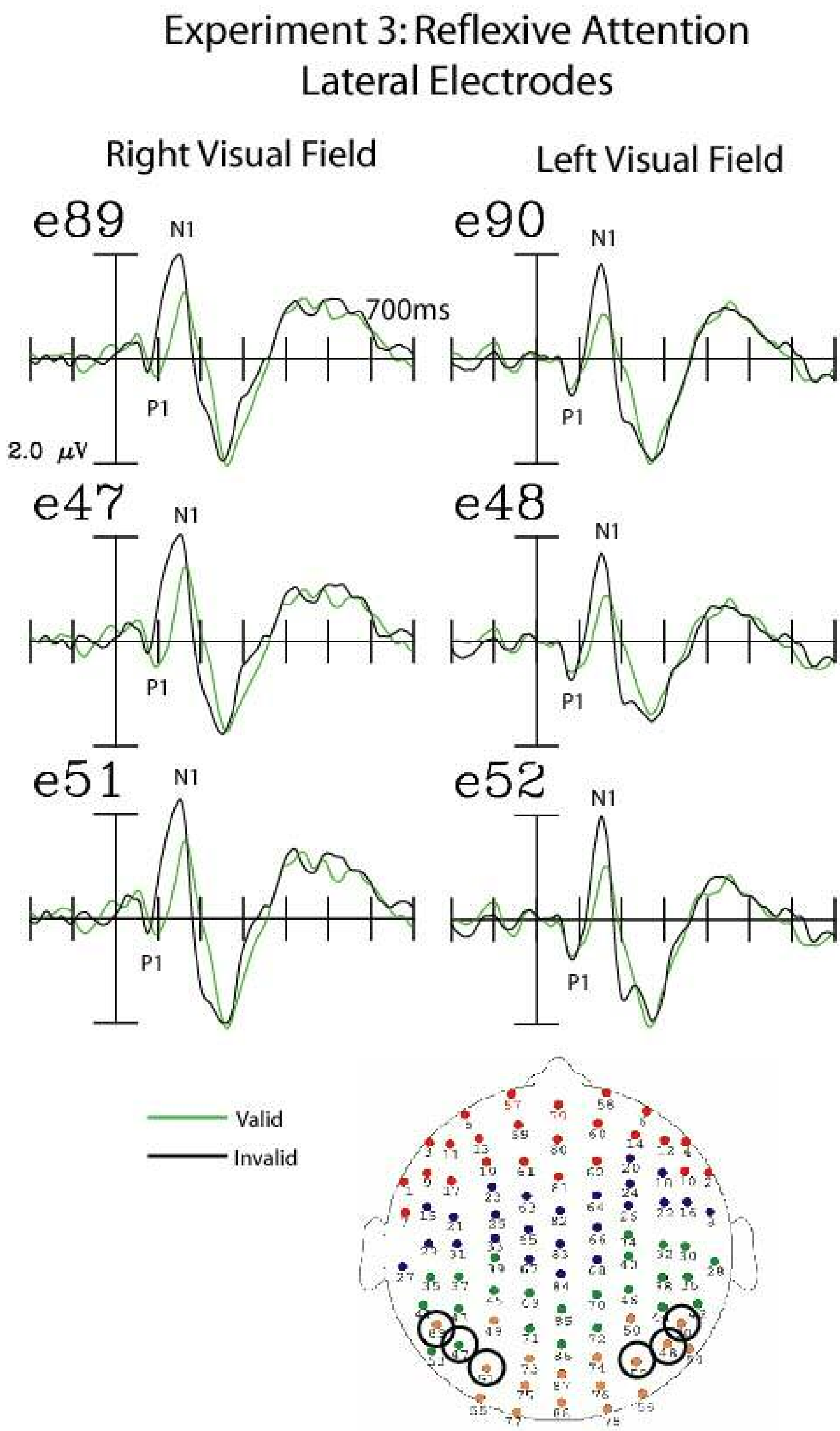


Figure 23. Experiment 3: Topographic maps of the P1 and N1 components for Reflexive attention blocks.

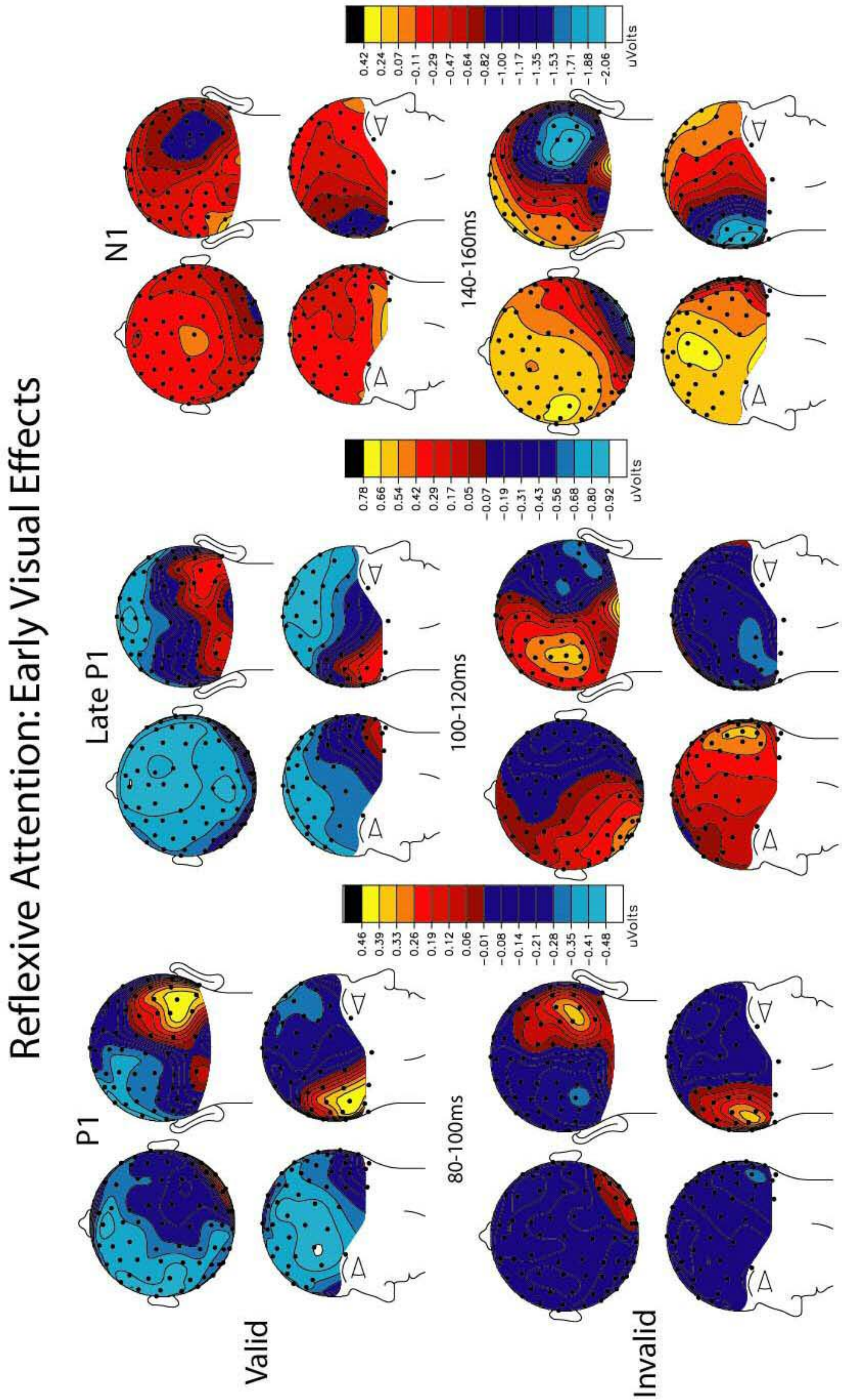


Figure 24. Experiment 3. A medial electrode showing validity effects of social, voluntary, and reflexive attention.

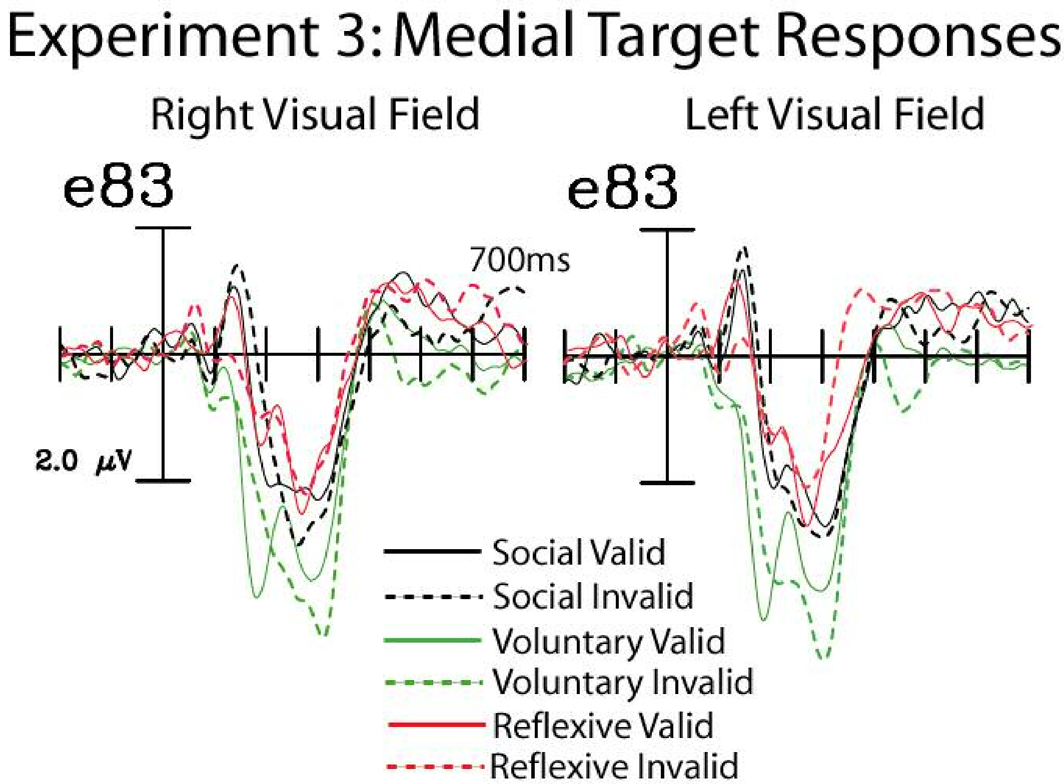


Figure 25.Experiment 3: ERP plots of medial electrodes showing later processing components for Social attention blocks.

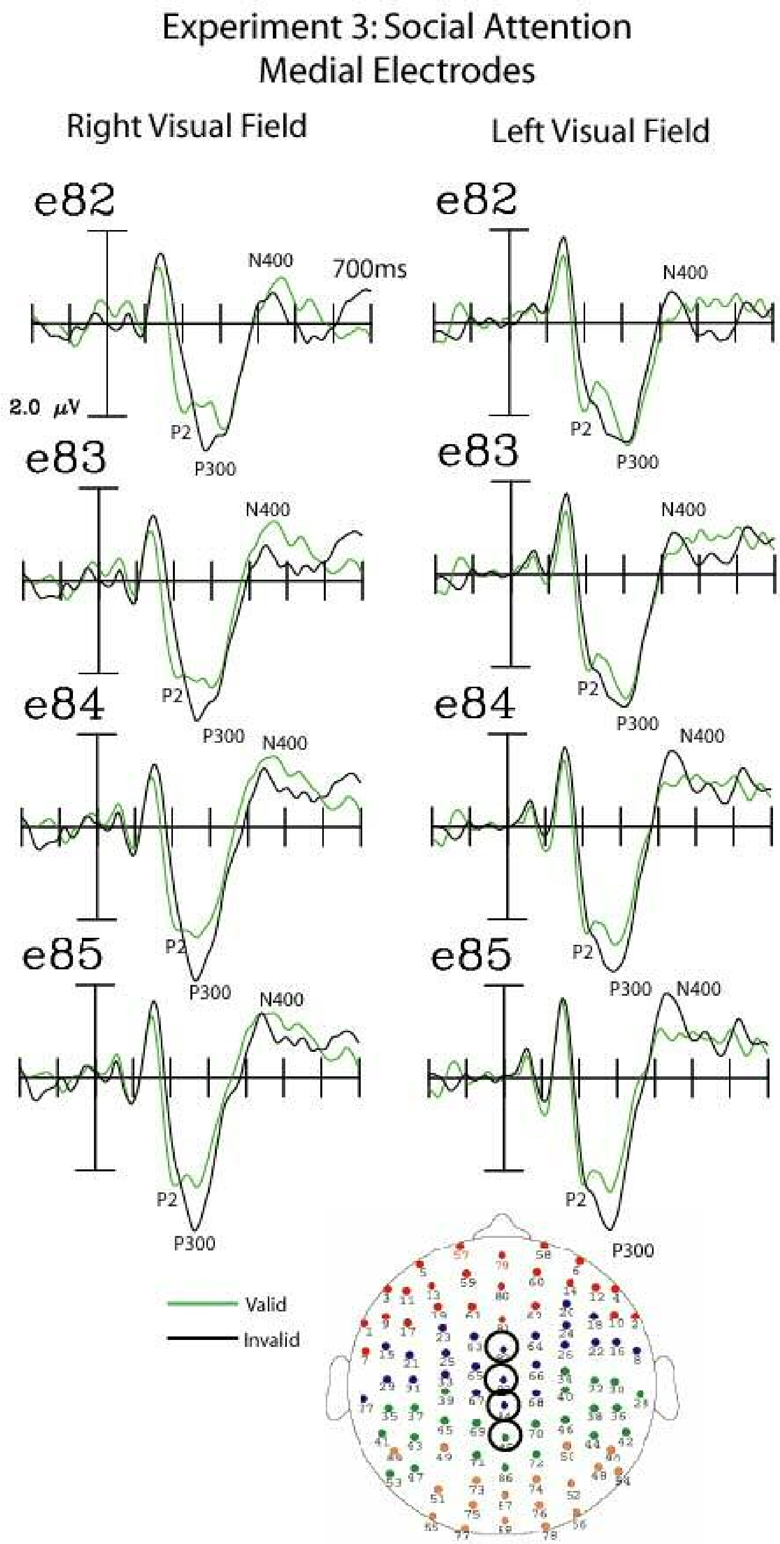


Figure 26. Experiment 3: Topographic maps of the P2, P300 and N400 components for Social attention blocks.

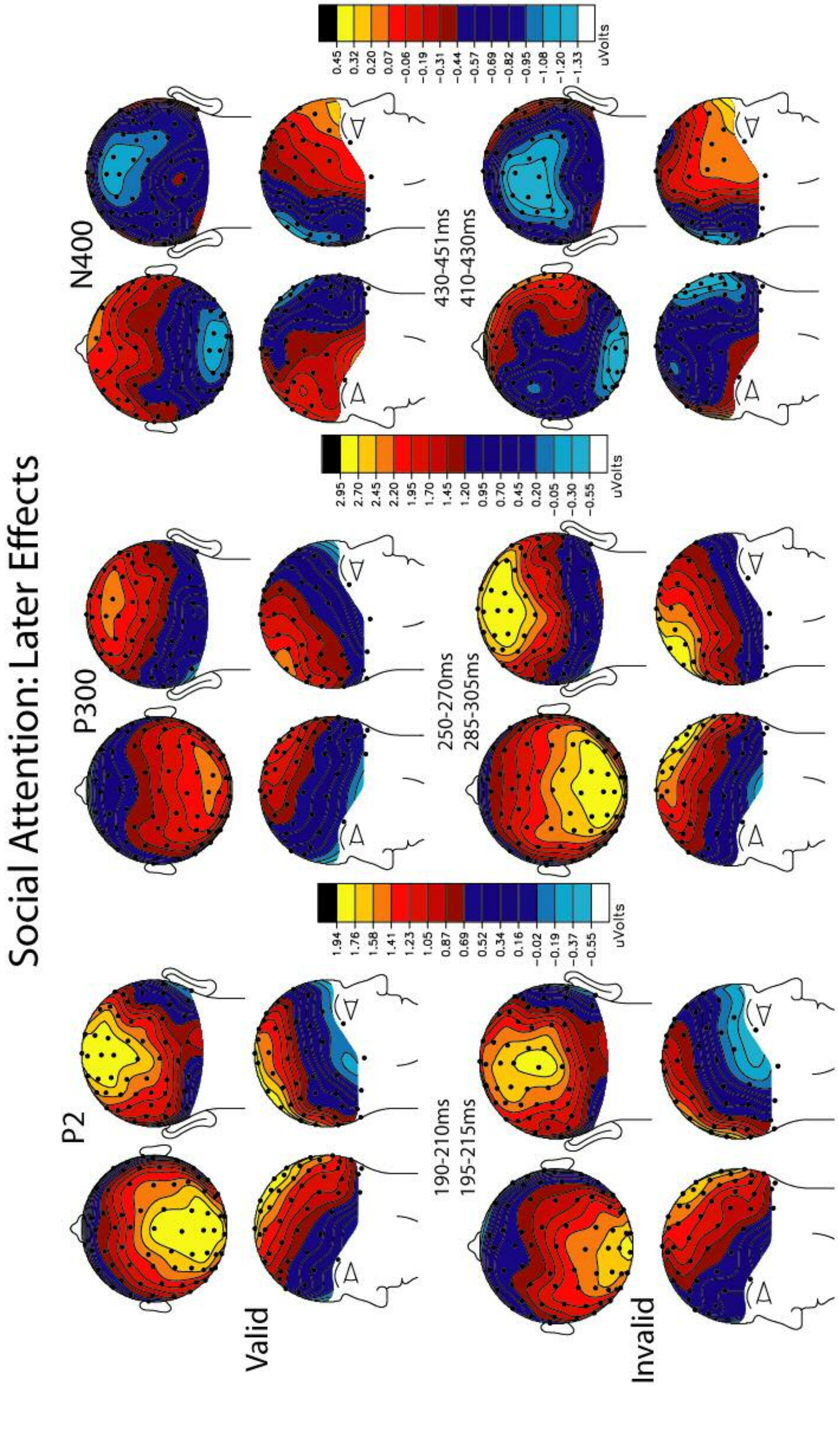


Figure 27.Experiment 3: ERP plots of medial electrodes showing later processing components for Voluntary attention blocks.

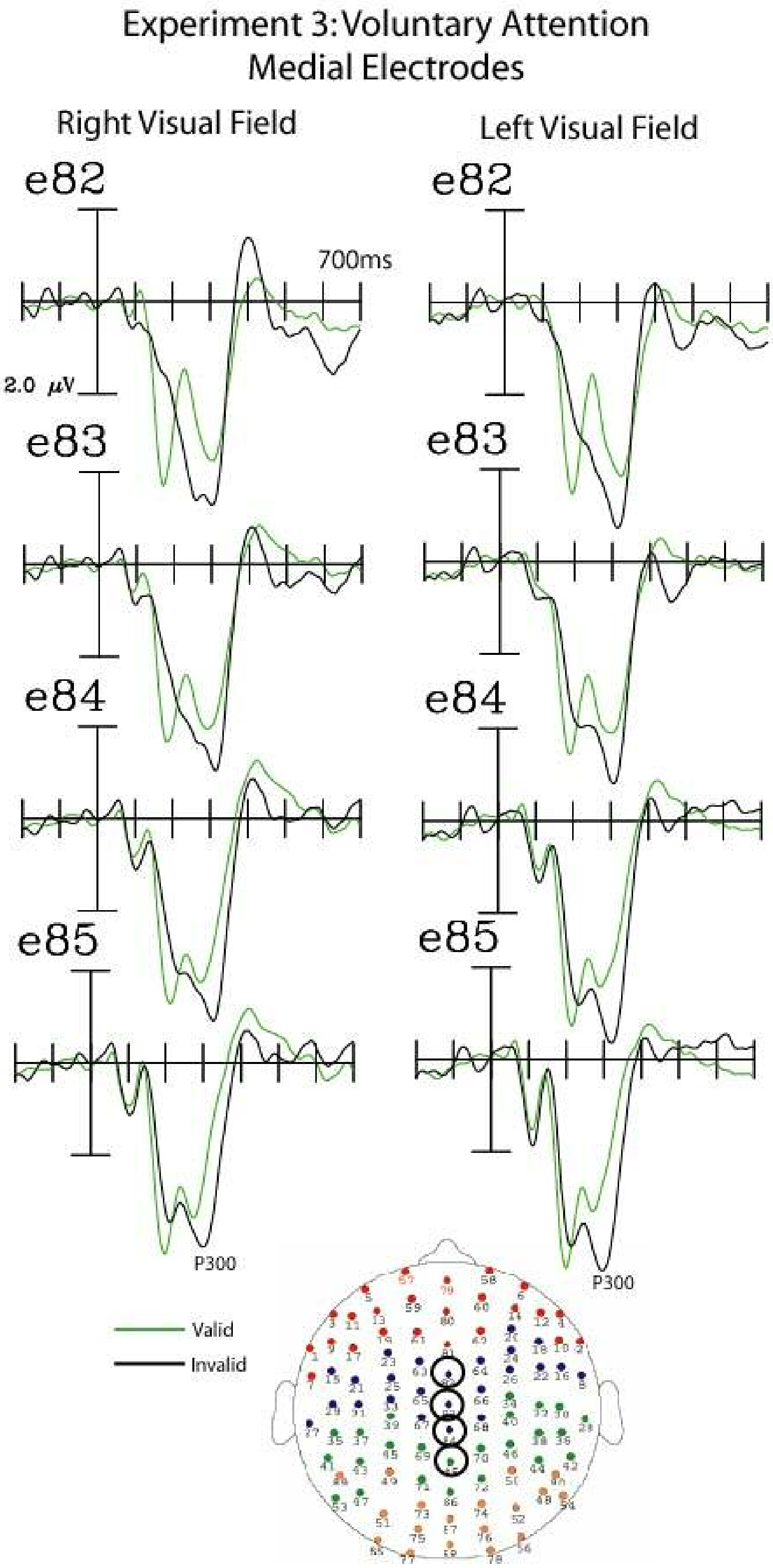


Figure 28. Experiment 3: Topographic maps of the P2, P300 and N400 components for Voluntary attention blocks.

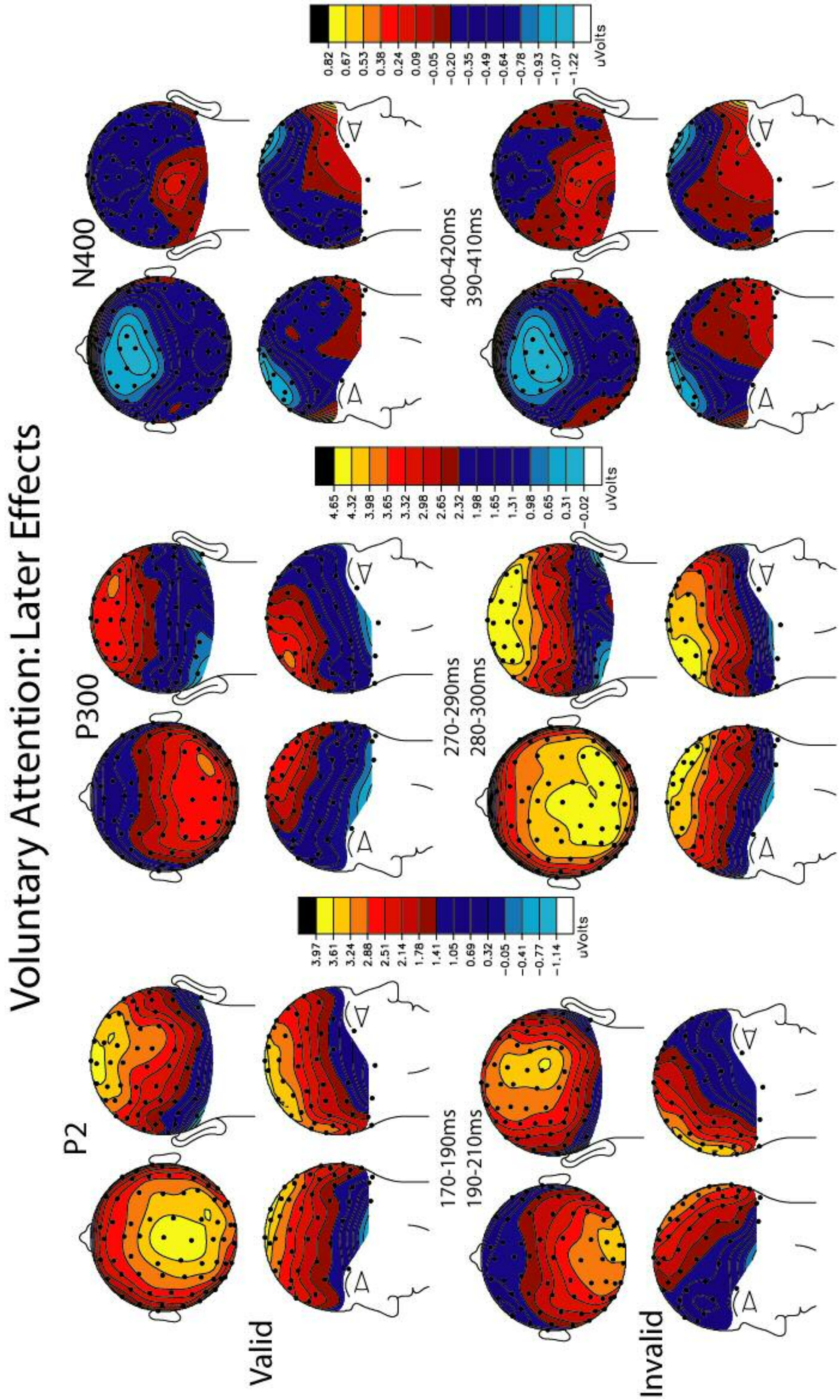


Figure 29.Experiment 3: ERP plots of medial electrodes showing later processing components for Reflexive attention blocks.

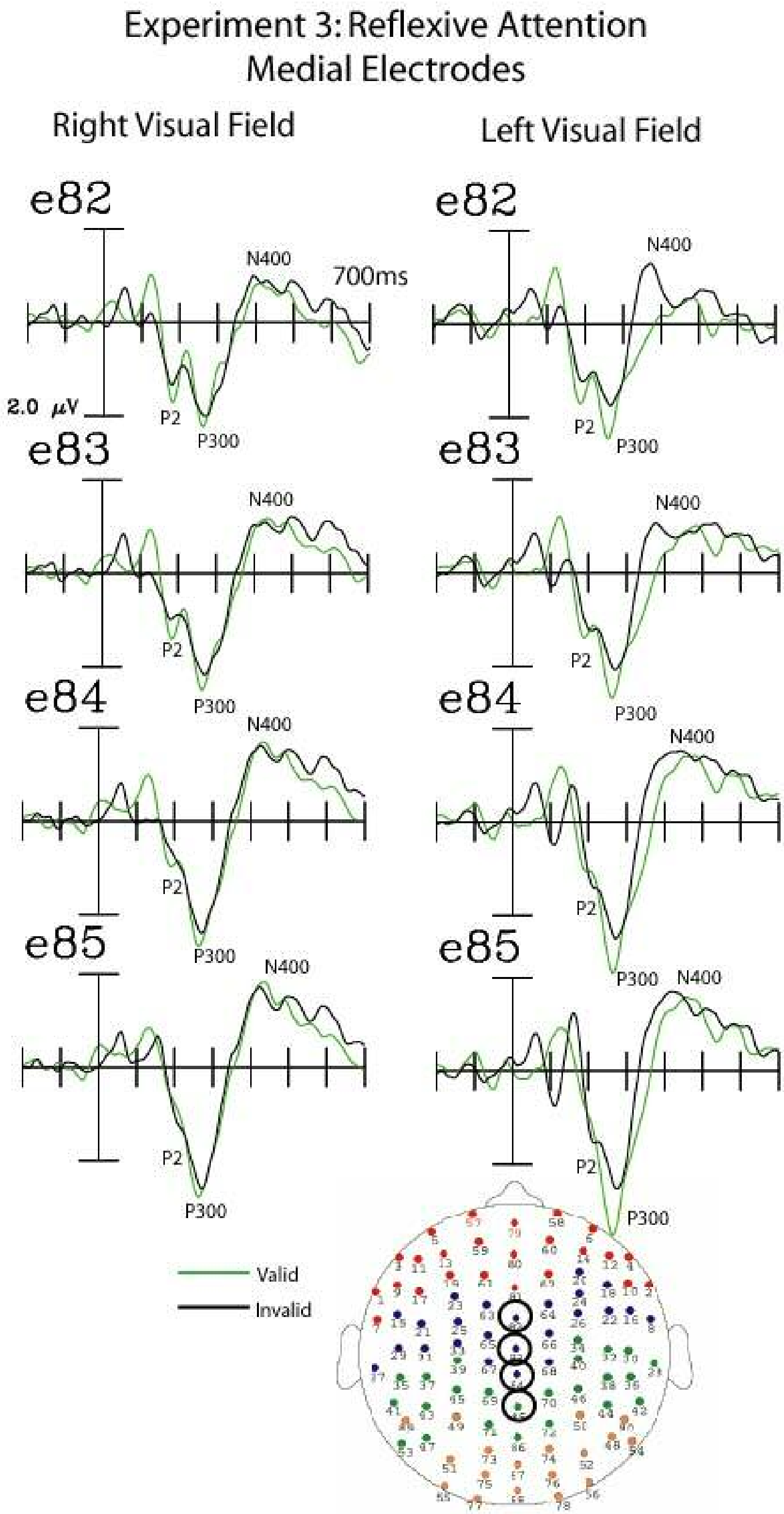
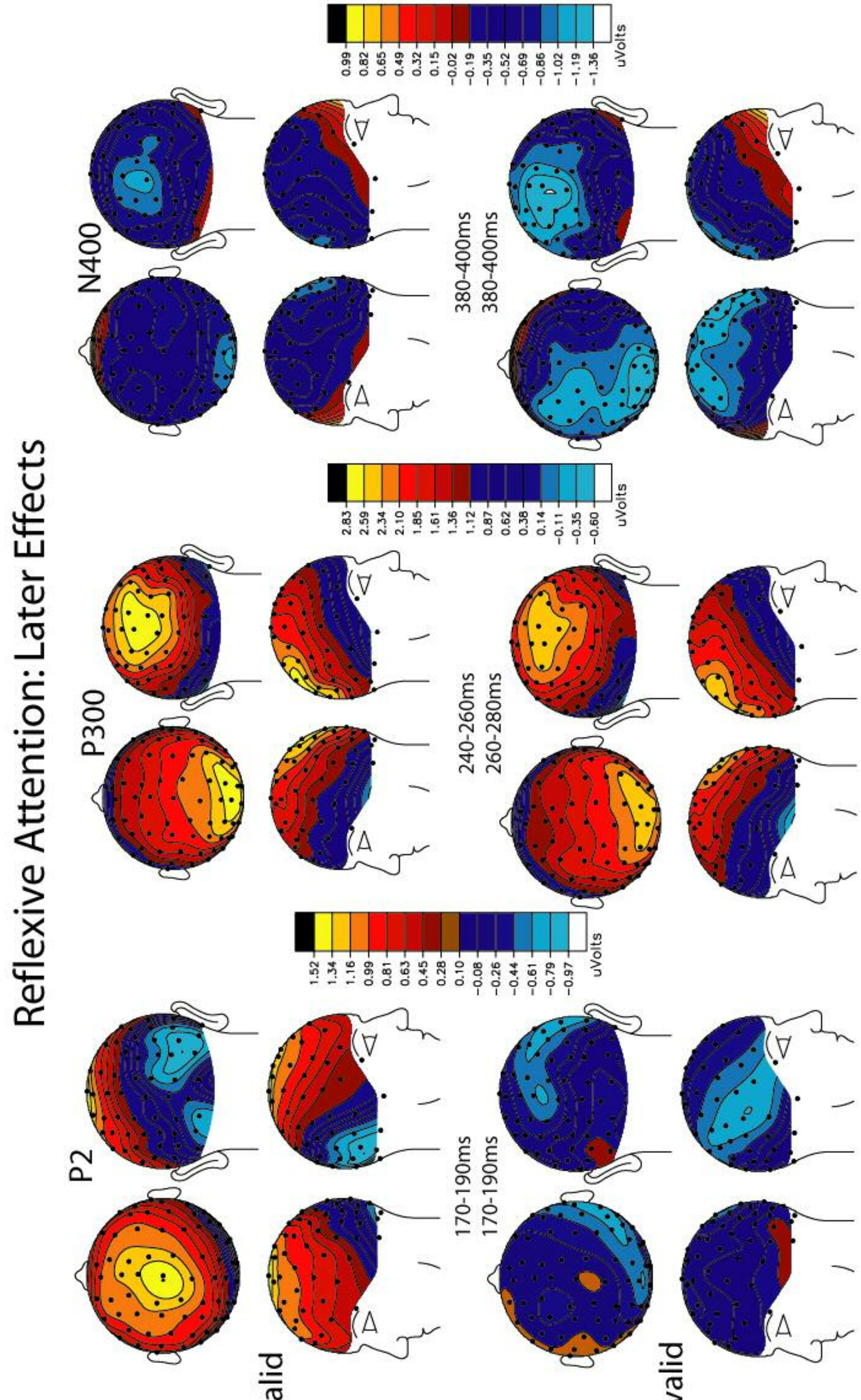


Figure 30. Experiment 3: Topographic maps of the P2, P300 and N400 components for Reflexive attention blocks.



Appendix: ANOVA tables for ERP component statistics

Experiment 2: P1 amplitude; All types of attention

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	32.91	2	16.45	10.21	0.0004*
Validity	0.65	1	0.65	0.68	0.4227
Att.Type x Validity	0.30	2	0.15	0.14	0.8667
Vis.Field	73.93	1	73.93	7.90	0.0132*
Att.Type x Vis. Field	1.70	2	0.85	0.72	0.4948
Validity x Vis.Field	0.05	1	0.05	0.05	0.8186
Att.Type x Val. X Vis.Field	0.11	2	0.06	0.14	0.8719
Electrode	1.75	1	1.75	3.40	0.0852
Att.Type x Electrode	0.99	2	0.50	8.27	0.0014*
Validity x Electrode	0.10	1	0.10	2.86	0.1117
Att.Type x Val x Electrode	0.03	2	0.01	0.24	0.7860
Vis.Field x Electrode	0.14	1	0.14	0.43	0.5198
Att.Type x Vis. Field x Electrode	0.03	2	0.02	0.41	0.6688
Validity x Vis.Field x Elctrode	0.01	1	0.01	0.33	0.5748
Att. Type x Val. x Vis.Field x Electrode	0.00	2	0.00	0.16	0.8528

Experiment 2: P1 Amplitude; Social Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.35	1	0.35	0.33	0.5744
Vis.Field	23.60	1	23.60	4.06	0.0623
Validity x Vis. Field	0.01	1	0.01	0.01	0.9148
Electrode	0.86	1	0.86	3.29	0.0899
Validity x Electrode	0.00	1	0.00	0.14	0.7183
Vis. Field x Electrode	0.09	1	0.09	0.62	0.4439
Val. x Vis.Field x Electrode	0.00	1	0.00	0.01	0.9110

Experiment 2: P1 Amplitude; Voluntary Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.00	1	0.00	0.00#	0.9658
Vis.Field	35.23	1	35.23	9.40	0.0079*
Validity x Vis.Field	0.16	1	0.16	0.38	0.5477
Electrode	1.87	1	1.87	9.05	0.0088*
Validity x Vis.Field	0.05	1	0.05	1.28	0.2757
Vis.Field x Electrode	0.00	1	0.00	0.03	0.8630
Val. x Vis.Field x Electrode	0.01	1	0.01	0.55	0.4703

Experiment 2: P1 Amplitude; Reflexive Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.60	1	0.60	0.40	0.5342
Vis.Field	16.81	1	16.81	7.79	0.0137*
Validity x Vis. Field	0.01	1	0.01	0.01	0.9387
Electrode	0.00	1	0.00	0.00#	0.9829
Validity x Electrode	0.08	1	0.08	0.83	0.3768
Vis. Field Electrode	0.08	1	0.08	0.66	0.4306
Val. x Vis.Field x Electrode	0.00	1	0.00	0.12	0.7384

Experiment 2: P1 latency; All types of attention

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	4307.58	2	2153.79	13.38	0.0001*
Validity	260.04	1	260.04	1.44	0.2490
Att.Type x Validity	114.08	2	57.04	0.60	0.5567
Vis. Field	1855.04	1	1855.04	3.26	0.0910
Att.Type x Vis. Field	100.08	2	50.04	0.49	0.6145
Validity x Vis.Field	247.04	1	247.04	5.48	0.0335*
Att.Type x Val. x Vis. Field	115.58	2	57.79	0.53	0.5955
Electrode	126.04	1	126.04	1.62	0.2221
Att.Type x Electrode	21.58	2	10.79	0.85	0.4376
Validity x Electrode	9.37	1	9.37	0.90	0.3584
Att.Type x Validity x Electrode	7.75	2	3.88	0.24	0.7896
Vis.Field x Electrode	234.37	1	234.37	3.52	0.0802
Att.Type x Vis.Field x Electrode	118.75	2	59.38	1.74	0.1924
Validity x Vis.Field x Electrode	0.38	1	0.38	0.09	0.7714
Att.Type x Val. x Vis.Field x Electrode	3.25	2	1.62	0.11	0.8923

Experiment 2: P1 Latency; Social Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	190.12	1	190.12	4.10	0.0611
Vis.Field	496.12	1	496.12	3.60	0.0774
Validity x Vis.Field	105.12	1	105.12	3.61	0.0769
Electrode	28.12	1	28.12	1.19	0.2921
Validity x Electrode	10.12	1	10.12	1.65	0.2180
Vis.Field x Electrode	6.12	1	6.12	0.41	0.5314
Val. x Vis.Field x Electrode	10.12	1	10.12	1.81	0.1984

Experiment 2: P1 Latency; Voluntary Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	2.00	1	2.00	0.03	0.8596
Vis.Field	128.00	1	128.00	2.26	0.1532
Validity x Vis.Field	40.50	1	40.50	0.80	0.3853
Electrode	18.00	1	18.00	1.90	0.1881
Validity x Electrode	0.50	1	0.50	0.24	0.6326
Vis.Field x Electrode	4.50	1	4.50	0.33	0.5732
Val. Vis.Field x Electrode	0.00	1	0.00	0.00	1.0000

Experiment 2: P1 Latency; Reflexive Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.12	1	0.12	0.00#	0.9590
Vis.Field	496.12	1	496.12	4.48	0.0515
Validity x Vis.Field	1.12	1	1.12	0.02	0.8884
Electrode	28.12	1	28.12	1.74	0.2064
Validity x Electrode	36.12	1	36.12	2.92	0.1084
Vis.Field x Electrode	91.12	1	91.12	3.39	0.0853
Val. x Vis.Field x Electrode	1.12	1	1.12	0.12	0.7341

Experiment 2: N1 amplitude; All types of attention

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	19.36	2	9.68	1.96	0.1583
Validity	4.23	1	4.23	1.92	0.1861
Att.Type x Validity	6.08	2	3.04	3.98	0.0294*
Vis.Field	90.01	1	90.01	15.14	0.0014*
Att.Type x Vis. Field	76.86	2	38.43	10.09	0.0004*
Validity x Vis. Field	0.42	1	0.42	0.30	0.5927
Att.Type x Val. x Vis.Field	0.35	2	0.18	0.23	0.7981
Electrode	0.06	1	0.06	0.24	0.6344
Att.Type x Electrode	0.38	2	0.19	2.26	0.1220
Validity x Electrode	0.02	1	0.02	1.04	0.3237
Att.Type x Val. x Electrode	0.44	2	0.22	4.49	0.0196*
Vis.Field x Electrode	0.05	1	0.05	0.54	0.4742
Att.Type x Vis.Field x Electrode	0.06	2	0.03	0.39	0.6772
Validity x Vis.Field x Electrode	0.01	1	0.01	0.65	0.4326
Att.Type x Val. x Vis.Field x Electrode	0.06	2	0.03	2.32	0.1155

Experiment 2: N1 Amplitude; Social Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.31	1	0.31	0.13	0.7220
Vis.Field	0.29	1	0.29	0.05	0.8220
Validity x Vis. Field	0.34	1	0.34	0.26	0.6187
Electrode	0.08	1	0.08	0.93	0.3507
Validity x Electrode	0.08	1	0.08	3.22	0.0931
Vis.Field x Electrode	0.02	1	0.02	0.65	0.4335
Val. x Vis.Field x Electrode	0.00	1	0.00	0.01	0.9263

Experiment 2: N1 Amplitude; Voluntary Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.12	1	0.12	0.14	0.7141
Vis.Field	2.71	1	2.71	0.55	0.4682
Validity x Vis.Field	0.02	1	0.02	0.03	0.8716
Electrode	0.13	1	0.13	1.06	0.3194
Validity x Electrode	0.08	1	0.08	2.35	0.1464
Vis.Field x Electrode	0.01	1	0.01	0.05	0.8254
Val. x Vis.Field x Electrode	0.02	1	0.02	1.32	0.2690

Experiment 2: N1 Amplitude; Reflexive Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	10.01	1	10.01	10.32	0.0058*
Vis.Field	3.61	1	3.61	1.02	0.3281
Validity x Vis.Field	0.04	1	0.04	0.06	0.8142
Electrode	0.01	1	0.01	0.08	0.7849
Validity x Electrode	0.17	1	0.17	1.93	0.1854
Vis.Field x Electrode	0.08	1	0.08	1.00	0.3326
Val. x Vis.Field x Electrode	0.01	1	0.01	0.26	0.6191

Experiment 2: N1 Latency; All types of attention

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	4697.33	2	2348.67	1.73	0.1940
Validity	1365.04	1	1365.04	1.81	0.1988
Att.Type x Validity	622.33	2	311.17	0.64	0.5326
Vis.Field	4959.37	1	4959.37	7.47	0.0154*
Att.Type x Vis.Field	2131.00	2	1065.50	2.49	0.0997
Validity x Vis.Field	84.38	1	84.38	0.12	0.7305
Att.Type x Val. x Vis.Field	1623.00	2	811.50	2.05	0.1461
Electrode	1457.04	1	1457.04	12.43	0.0031*
Att.Type x Electrode	42.33	2	21.17	0.17	0.8434
Validity x Electrode	222.04	1	222.04	2.04	0.1741
Att.Type x Val. x Electrode	121.33	2	60.67	0.78	0.4659
Vis.Field x Electrode	165.38	1	165.38	5.18	0.0380*
Att.Type x Vis.Field x Electrode	13.00	2	6.50	0.25	0.7805
Validity x Vis.Field x Electrode	12.04	1	12.04	0.38	0.5468
Att.Type x Val. x Vis.Field x Electrode	126.33	2	63.17	1.62	0.2144

Experiment 2: N1 Latency; Social Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	144.50	1	144.50	6.70	0.0206*
Vis.Field	338.00	1	338.00	2.05	0.1728
Validity x Vis.Field	0.50	1	0.50	0.04	0.8503
Electrode	60.50	1	60.50	8.77	0.0097*
Validity x Electrode	8.00	1	8.00	2.73	0.1194
Vis.Field x Electrode	0.50	1	0.50	0.17	0.6839
Val. x Vis.Field x Electrode	2.00	1	2.00	1.15	0.2997

Experiment 2: N1 Latency; Voluntary Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	128.00	1	128.00	8.57	0.0104*
Vis.Field	18.00	1	18.00	0.22	0.6483
Validity x Vis.Field	8.00	1	8.00	0.20	0.6632
Electrode	50.00	1	50.00	7.98	0.0128*
Validity x Electrode	0.00	1	0.00	0.00	1.0000
Vis.Field x Electrode	18.00	1	18.00	3.14	0.0967
Val. x Vis.Field x Electrode	0.00	1	0.00	0.00	1.0000

Experiment 2: N1 Latency; Reflexive Attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	98.00	1	98.00	1.24	0.2831
Vis.Field	4.50	1	4.50	0.05	0.8328
Validity x Vis.Field	144.50	1	144.50	3.37	0.0864
Electrode	128.00	1	128.00	16.55	0.0010*
Validity x Electrode	0.00	1	0.00	0.00	1.0000
Vis.Field x Electrode	4.50	1	4.50	0.38	0.5445
Val. x Vis.Field x Electrode	0.50	1	0.50	0.17	0.6839

Experiment 2: P2 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	50.88	2	25.44	6.95	0.0033*
Validity	2.02	1	2.02	0.61	0.4478
AttType x Validity	91.02	2	45.51	9.41	0.0007*
Vis.Field	0.66	1	0.66	0.16	0.6977
Att.Type x Vis.Field	0.18	2	0.09	0.04#	0.9612
Validity x Vis.Field	2.04	1	2.04	2.61	0.1273
Att.Type x Val. x Vis.Field	2.95	2	1.48	1.26	0.2970
Electrode	2.54	1	2.54	1.60	0.2248
Att.Type x Electrode	1.05	2	0.52	5.81	0.0074*
Validity x Electrode	4.41	1	4.41	17.29	0.0008*
Att.Type x Val. x Electrode	0.79	2	0.40	3.15	0.0571
Vis.Field x Electrode	0.01	1	0.01	0.03	0.8686
Att.Type x Vis.Field x Electrode	0.01	2	0.01	0.08	0.9201
Validity x Vis.Field x Electrode	0.11	1	0.11	3.47	0.0824
Att.Type x Val. x Vis.Field x Electrode	0.13	2	0.07	2.05	0.1464

Experiment 2: P2 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	13.62	1	13.62	2.63	0.1255
Vis.Field	0.13	1	0.13	0.11	0.7462
Validity x Vis.Field	0.02	1	0.02	0.01	0.9072
Electrode	1.65	1	1.65	2.55	0.1310
Validity x Electrode	1.56	1	1.56	11.87	0.0036*
Vis.Field x Electrode	0.00	1	0.00	0.00#	0.9586
Val. x Vis Field x Electrode	0.07	1	0.07	6.09	0.0261*

Experiment 2: P2 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	32.02	1	32.02	10.52	0.0054*
Vis.Field	0.06	1	0.06	0.03	0.8643
Validity x Vis.Field	4.96	1	4.96	5.60	0.0319*
Electrode	1.94	1	1.94	3.39	0.0856
Validity x Electrode	3.32	1	3.32	12.80	0.0027*
Vis.Field x Electrode	0.00	1	0.00	0.01	0.9278
Val. x Vis.Field x Electrode	0.01	1	0.01	0.31	0.5880

Experiment 2: P2 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	47.41	1	47.41	9.90	0.0067*
Vis.Field	0.65	1	0.65	0.12	0.7366
Validity x Vis.Field	0.01	1	0.01	0.01	0.9044
Electrode	0.01	1	0.01	0.01	0.9085
Validity x Electrode	0.32	1	0.32	2.75	0.1179
Vis.Field x Electrode	0.02	1	0.02	0.23	0.6407
Val. x Vis.Field x Electrode	0.16	1	0.16	3.06	0.1008

Experiment 2: P300 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	16.99	2	8.50	0.98	0.3873
Validity	45.32	1	45.32	9.21	0.0084*
Att.Type x Validity	71.62	2	35.81	3.94	0.0302*
Vis.Field	2.02	1	2.02	0.68	0.4213
Att.Type x Vis.Field	7.78	2	3.89	1.95	0.1604
Validity x Vis.Field	0.89	1	0.89	0.22	0.6469
Att.Type x Val. x Vis.Field	3.68	2	1.84	0.58	0.5666
Electrode	6.19	2	3.10	3.88	0.0316*
Att.Type x Electrode	1.12	4	0.28	2.83	0.0323*
Validity x Electrode	0.45	2	0.23	4.70	0.0167*
Att.Type x Val. x Electrode	0.43	4	0.11	1.96	0.1121
Vis.Field x Electrode	0.24	2	0.12	1.11	0.3433
Att.Type x Vis.Field x Electrode	0.04	4	0.01	0.32	0.8645
Validity x Vis.Field x Electrode	0.02	2	0.01	0.26	0.7728
Att.Type x Val. x Vis.Field x Electrode	0.79	4	0.20	4.02	0.0059*

Experiment 2: P300 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	10.88	1	10.88	1.24	0.2830
Vis.Field	3.02	1	3.02	2.07	0.1707
Validity x Vis. Field	0.86	1	0.86	0.24	0.6299
Electrode	2.05	2	1.03	3.63	0.0388*
Validity x Electrode	0.72	2	0.36	6.15	0.0058*
Vis. Field x Electrode	0.13	2	0.07	1.11	0.3438
Val. x Vis.Field x Electrode	0.20	2	0.10	1.66	0.2066

Experiment 2: P300 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	102.89	1	102.89	27.33	0.0001*
Vis.Field	4.70	1	4.70	3.82	0.0695
Validity x Vis.Field	2.78	1	2.78	2.07	0.1705
Electrode	4.55	2	2.28	5.33	0.0105*
Validity x Electrode	0.14	2	0.07	1.89	0.1691
Vis.Field x Electrode	0.02	2	0.01	0.10	0.9083
Val. x Vis.Field x Electrode	0.18	2	0.09	5.77	0.0076*

Experiment 2: P300 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	3.17	1	3.17	0.30	0.5916
Vis.Field	2.08	1	2.08	0.49	0.4953
Validity x Vis.Field	0.93	1	0.93	0.17	0.6872
Electrode	0.71	2	0.35	1.24	0.3032
Validity x Electrode	0.02	2	0.01	0.16	0.8556
Vis.Field x Electrode	0.14	2	0.07	2.12	0.1372
Val. x Vis.Field x Electrode	0.43	2	0.21	3.80	0.0338*

Experiment 2: N400 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	17.00	2	8.50	1.06	0.3585
Validity	6.40	1	6.40	3.18	0.0947
Att.Type x Validity	27.08	2	13.54	7.31	0.0026*
Vis.Field	0.94	1	0.94	0.29	0.5976
Att.Type x Vis Field	8.55	2	4.28	2.17	0.1316
Validity x Vis.Field	1.02	1	1.02	1.09	0.3139
Att.Type x Val. x Vis.Field	1.09	2	0.55	0.54	0.5859
Electrode	0.76	2	0.38	1.29	0.2893
Att.Type x Electrode	0.40	4	0.10	1.45	0.2284
Validity x Electrode	0.04	2	0.02	0.46	0.6341
Att.Type x Val. x Electrode	0.04	4	0.01	0.44	0.7783
Vis.Field x Electrode	1.55	2	0.78	14.61	0.0000*
Att.Type x Vis.Field x Electrode	0.17	4	0.04	1.23	0.3095
Validity x Vis.Field x Electrode	0.00	2	0.00	0.10	0.9028
Att.Type x Val. x VisField x Electrode	0.16	4	0.04	1.97	0.1111

Experiment 2: N400 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	6.86	1	6.86	4.78	0.0451*
Vis.Field	1.33	1	1.33	0.39	0.5399
Validity x Vis. Field	0.26	1	0.26	0.19	0.6712
Electrode	0.69	2	0.34	2.52	0.0974
Validity x Electrode =	0.06	2	0.03	1.23	0.3077
Vis. Field x Electrode	0.81	2	0.41	10.16	0.0004*
Val. x Vis.Field x Electrode	0.00	2	0.00	0.03#	0.9707

Experiment 2: N400 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	20.50	1	20.50	14.91	0.0015*
Vis.Field	3.03	1	3.03	1.75	0.2060
Validity x Vis.Field	1.84	1	1.84	2.20	0.1584
Electrode	0.28	2	0.14	1.15	0.3313
Validity x Electrode	0.02	2	0.01	0.21	0.8125
Vis.Field x Electrode	0.70	2	0.35	7.77	0.0019*
Val. x Vis.Field x Electrode	0.09	2	0.04	3.23	0.0537

Experiment 2: N400 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	6.11	1	6.11	2.11	0.1673
Vis.Field	5.14	1	5.14	2.49	0.1353
Validity x Vis.Field	0.01	1	0.01	0.02	0.8933
Electrode	0.19	2	0.09	0.55	0.5854
Validity x Electrode	0.01	2	0.00	0.13	0.8797
Vis.Field x Electrode	0.22	2	0.11	2.76	0.0792
Val. x Vis.Field x Electrode	0.08	2	0.04	1.22	0.3104

Experiment 3: P1 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	54.26	2	27.13	19.39	0.0000*
Validity	0.11	1	0.11	0.12	0.7297
Att.Type x Validity	0.83	2	0.42	0.38	0.6849
Vis.Field	32.16	1	32.16	12.47	0.0030*
Att.Type x Vis.Field	26.74	2	13.37	11.53	0.0002*
Validity x Vis.Field	0.08	1	0.08	0.14	0.7150
Att.Type x Val. x Vis.Field	1.74	2	0.87	1.60	0.2181
Electrode	0.41	1	0.41	0.65	0.4332
Att.Type x Electrode	1.66	2	0.83	6.42	0.0048*
Validity x Electrode	0.03	1	0.03	1.04	0.3238
Att.Type x Val. x Electrode	0.05	2	0.02	0.48	0.6245
Vis.Field x Electrode	0.31	1	0.31	1.49	0.2415
Att.Type x Vis. Field x Elctrode	0.05	2	0.02	0.46	0.6361
Validity x Vis. Field x Electrode	0.02	1	0.02	0.47	0.5029
Att.Type x Val. x Vis.Field x Electrode	0.11	2	0.06	1.26	0.2990

Experiment 3: P1 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.29	1	0.29	0.29	0.5969
Vis.Field	0.08	1	0.08	0.07	0.7904
Validity x Vis.Field	0.68	1	0.68	1.04	0.3229
Electrode	0.09	1	0.09	0.57	0.4603
Validity x Electrode	0.00	1	0.00	0.12	0.7388
Vis.Field x Electrode	0.02	1	0.02	0.17	0.6868
Val. x Vis.Field x Electrode	0.03	1	0.03	0.69	0.4176

Experiment 3: P1 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.18	1	0.18	0.38	0.5487
Vis.Field	49.43	1	49.43	17.44	0.0008*
Validity x Vis.Field	0.07	1	0.07	0.16	0.6983
Electrode	1.98	1	1.98	3.04	0.1015
Validity x Electrode	0.01	1	0.01	1.37	0.2607
Vis.Field x Electrode	0.16	1	0.16	1.13	0.3044
Val. x Vis.Field x Electrode	0.02	1	0.02	2.00	0.1776

Experiment 3: P1 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.48	1	0.48	0.30	0.5939
Vis.Field	9.40	1	9.40	9.06	0.0088*
Validity x Vis. Field	1.07	1	1.07	2.00	0.1775
Electrode	0.00	1	0.00	0.00#	0.9781
Validity x Electrode	0.06	1	0.06	0.71	0.4133
Vis.Field x Electrode	0.17	1	0.17	4.23	0.0576
Val. x Vis.Field x Electrode	0.08	1	0.08	1.08	0.3159

Experiment 3: P1 Latency; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	639.08	2	319.54	1.27	0.2957
Validity	570.38	1	570.38	1.72	0.2099
Att.Type x Validity	1054.75	2	527.38	2.25	0.1229
Vis.Field	4293.38	1	4293.38	5.77	0.0297*
Att.Type x Vis.Field	900.75	2	450.37	2.32	0.1153
Validity x Vis.Field	570.37	1	570.37	5.74	0.0301*
Att.Type x Val. x Vis.Field	2395.75	2	1197.88	8.55	0.0011*
Electrode	234.38	1	234.38	4.13	0.0601
Att.Type x Electrode	45.25	2	22.62	0.82	0.4519
Validity x Electrode	5.04	1	5.04	0.12	0.7352
Att.Type x Val. x Electrode	18.58	2	9.29	0.52	0.5983
Vis.Field x Electrode	77.04	1	77.04	2.34	0.1466
Att.Type x Vis.Field x Electrode	21.58	2	10.79	0.47	0.6302
Validity x Vis.Field x Electrode	35.04	1	35.04	1.51	0.2382
Att.Type x Val. x Vis.Field x Electrode	7.58	2	3.79	0.20	0.8205

Experiment 3: P1 Latency; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	24.50	1	24.50	0.39	0.5436
Vis.Field	1682.00	1	1682.00	18.05	0.0007*
Validity x Vis.Field	4.50	1	4.50	0.21	0.6544
Electrode	40.50	1	40.50	1.49	0.2409
Validity x Electrode	18.00	1	18.00	1.42	0.2517
Vis.Field x Electrode	0.50	1	0.50	0.03	0.8545
Val. x Vis.Field x Electrode	8.00	1	8.00	1.50	0.2396

Experiment 3: P1 Latency; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	10.12	1	10.12	0.38	0.5489
Vis.Field	990.12	1	990.12	5.38	0.0349*
Validity x Vis.Field	36.12	1	36.12	1.98	0.1799
Electrode	36.12	1	36.12	2.92	0.1084
Validity x Electrode	1.12	1	1.12	0.11	0.7475
Vis.Field x Electrode	10.12	1	10.12	0.97	0.3393
Val. x Vis.Field x Electrode	10.12	1	10.12	0.97	0.3393

Experiment 3: P1 Latency; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	648.00	1	648.00	3.02	0.1028
Vis.Field	50.00	1	50.00	0.71	0.4130
Validity x Vis.Field	1058.00	1	1058.00	13.47	0.0023*
Electrode	50.00	1	50.00	3.57	0.0783
Validity x Electrode	2.00	1	2.00	0.15	0.7054
Vis.Field x Electrode	0.00	1	0.00	0.00	1.0000
Val x Vis.Field x Electrode	32.00	1	32.00	3.87	0.0679

Experiment 3: Late P1 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	54.87	2	27.44	15.54	0.0000*
Validity	5.22	1	5.22	1.64	0.2193
Att.Type x Validity	19.15	2	9.58	5.49	0.0093*
Vis.Field	76.01	1	76.01	15.33	0.0014*
Att.Type x Vis.Field	12.05	2	6.03	3.65	0.0383*
Validity x Vis.Field	2.12	1	2.12	5.01	0.0408*
Att.Type x Validity x Vis.Field	8.08	2	4.04	4.92	0.0142*
Electrode	0.43	1	0.43	0.42	0.5265
Att.Type x Electrode	1.03	2	0.51	4.29	0.0230*
Validity x Electrode	0.18	1	0.18	4.86	0.0435*
Att.Type x Val. X Electrode	0.12	2	0.06	0.89	0.4223
Vis.Field x Electrode	0.63	1	0.63	2.52	0.1331
Att.Type x Vis.Field x Electrode	0.04	2	0.02	0.24	0.7878
Validity x Vis.Field x Electrode	0.00	1	0.00	0.16	0.6941
Att.Type x Val. x Vis.Field x Electrode	0.03	2	0.01	0.37	0.6912

Experiment 3: Late P1 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.05	1	0.05	0.04	0.8514
Vis.Field	10.76	1	10.76	5.20	0.0377*
Validity x Vis.Field	0.97	1	0.97	1.51	0.2380
Electrode	0.00	1	0.00	0.00#	0.9539
Validity x Electrode	0.00	1	0.00	0.00	0.9474
Vis.Field x Electrode	0.12	1	0.12	0.81	0.3830
Validity x Vis.Field x Electrode	0.02	1	0.02	0.68	0.4222

Experiment 3: Late P1 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.50	1	0.50	0.96	0.3428
Vis.Field	61.45	1	61.45	12.10	0.0034*
Validity x Vis.Field	0.27	1	0.27	0.51	0.4854
Electrode	1.46	1	1.46	2.09	0.1689
Validity x Electrode	0.07	1	0.07	3.18	0.0948
Vis.Field x Electrode	0.18	1	0.18	0.88	0.3625
Val. X Vis.Field x Electrode	0.01	1	0.01	0.40	0.5361

Experiment 3: Late P1 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	23.82	1	23.82	4.89	0.0429*
Vis.Field	15.85	1	15.85	14.21	0.0019*
Validity x Vis.Field	8.96	1	8.96	9.95	0.0065*
Electrode	0.00	1	0.00	0.01	0.9312
Validity x Electrode	0.22	1	0.22	2.05	0.1727
Vis.Field x Electrode	0.37	1	0.37	6.22	0.0248*
Val. x Vis.Field x Electrode	0.00	1	0.00	0.02	0.8987

Experiment 3: N1 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	17.39	2	8.70	2.35	0.1126
Validity	10.00	1	10.00	6.67	0.0208*
Att.Type x Validity	18.19	2	9.09	11.56	0.0002*
Vis.Field	11.57	1	11.57	0.85	0.3709
Att.Type x Vis.Field	0.06	2	0.03	0.01#	0.9916
Validity x Vis.Field	0.41	1	0.41	0.67	0.4265
Att.Type x Val. x Vis.Field	0.21	2	0.11	0.15	0.8624
Electrode	4.86	1	4.86	7.98	0.0128*
Att.Type x Electrode	3.02	2	1.51	11.11	0.0002*
Validity x Electrode	0.08	1	0.08	7.19	0.0171*
Att.Type x Val. x Electrode	0.06	2	0.03	1.12	0.3382
Vis.Field x Electrode	1.06	1	1.06	3.36	0.0868
Att.Type x Vis.Field xElectrode	0.23	2	0.11	2.30	0.1175
Validity x Vis.Field x Electrode	0.02	1	0.02	1.01	0.3299
Att.Type x Val. x Vis.Field x Electrode	0.02	2	0.01	0.59	0.5600

Experiment 3: N1 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.02	1	0.02	0.03	0.8712
Vis.Field	3.77	1	3.77	0.30	0.5941
Validity x Vis.Field	0.28	1	0.28	0.31	0.5886
Electrode	6.99	1	6.99	14.34	0.0018*
Validity x Electrode	0.03	1	0.03	1.76	0.2042
Vis.Field x Electrode	0.97	1	0.97	3.88	0.0677
Val x VisField x Electrode	0.00	1	0.00	0.00#	0.9728

Experiment 3: N1 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.11	1	0.11	0.14	0.7150
Vis.Field	4.60	1	4.60	0.76	0.3972
Validity x Vis.Field	0.34	1	0.34	0.92	0.3520
Electrode	0.82	1	0.82	3.56	0.0788
Validity x Electrode	0.11	1	0.11	4.39	0.0536
Vis.Field x Electrode	0.14	1	0.14	1.33	0.2661
Val x Vis.Field x Electrode	0.03	1	0.03	8.28	0.0115*

Experiment 3: N1 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	28.06	1	28.06	19.18	0.0005*
Vis.Field	3.26	1	3.26	1.93	0.1850
Validity x Vis.Field	0.00	1	0.00	0.00#	0.9928
Electrode	0.07	1	0.07	0.44	0.5167
Validity x Electrode	0.00	1	0.00	0.03	0.8624
Vis.Field x Electrode	0.18	1	0.18	2.92	0.1084
Val x Vis.Field x Electrode	0.01	1	0.01	0.25	0.6223

Experiment 3: N1 Latency; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	16198.08	2	8099.04	17.85	0.0000*
Validity	805.04	1	805.04	0.79	0.3868
Att.Type x Validity	4504.08	2	2252.04	3.68	0.0372*
Vis.Field	852.04	1	852.04	0.86	0.3679
Att.Type x Vis.Field	111.58	2	55.79	0.07	0.9308
Validity x Vis.Field	570.37	1	570.37	1.15	0.3008
Att.Type x Val. x Vis.Field	30.25	2	15.13	0.06	0.9400
Electrode	198.37	1	198.37	2.10	0.1675
Att.Type x Electrode	45.75	2	22.88	0.16	0.8541
Validity x Electrode	7.04	1	7.04	0.17	0.6866
Att.Type x Val. x Electrode	19.08	2	9.54	0.42	0.6601
Vis.Field x Electrode	260.04	1	260.04	1.61	0.2235
Att.Type x Vis.Field x Electrode	205.58	2	102.79	0.86	0.4337
Validity x Vis.Field x Electrode	7.04	1	7.04	0.30	0.5920
Att.Type x Val. x Vis.Field x Electrode	27.58	2	13.79	0.47	0.6265

Experiment 3: N1 Latency; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	1.12	1	1.12	0.02	0.8824
Vis.Field	171.12	1	171.12	1.12	0.3062
Validity x Vis.Field	6.12	1	6.12	0.07	0.8016
Electrode	91.12	1	91.12	7.82	0.0136*
Validity x Electrode	3.12	1	3.12	0.37	0.5524
Vis.Field x Electrode	6.12	1	6.12	0.59	0.4546
Val x Vis.Field x Electrode	10.12	1	10.12	0.95	0.3452

Experiment 3: N1 Latency; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	32.00	1	32.00	2.35	0.1459
Vis.Field	338.00	1	338.00	3.50	0.0811
Validity x Vis.Field	98.00	1	98.00	4.68	0.0470*
Electrode	18.00	1	18.00	4.09	0.0613
Validity x Electrode	0.00	1	0.00	0.00	1.0000
Vis.Field x Electrode	0.00	1	0.00	0.00	1.0000
Val x Vis.Field x Electrode	2.00	1	2.00	1.67	0.2162

Experiment 3: N1 Latency; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	630.12	1	630.12	3.00	0.1038
Vis.Field	6.12	1	6.12	0.08	0.7844
Validity x Vis.Field	45.12	1	45.12	0.62	0.4427
Electrode	91.12	1	91.12	18.26	0.0007*
Validity x Electrode	3.12	1	3.12	0.34	0.5699
Vis.Field x Electrode	1.12	1	1.12	0.22	0.6461
Val x Vis.Field x Electrode	3.12	1	3.12	1.34	0.2644

Experiment 3: P2 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	326.39	2	163.19	16.96	0.0000*
Validity	44.44	1	44.44	7.11	0.0176*
Att.Type x Validity	10.28	2	5.14	1.32	0.2813
Vis.Field	2.45	1	2.45	0.68	0.4211
Att.Type x Vis.Field	7.77	2	3.89	1.68	0.2037
Validity x Vis. Field	1.87	1	1.87	0.79	0.3890
Att.T Val. x Vis.Field	3.39	2	1.69	0.78	0.4696
Electrode	0.06	1	0.06	0.07	0.7961
Att.Type x Electrode	6.12	2	3.06	15.50	0.0000*
Validity x Electrode	2.23	1	2.23	24.14	0.0002*
Att.Type x Val. x Electrode	2.22	2	1.11	7.31	0.0026*
Vis.Field x Electrode	0.02	1	0.02	0.12	0.7362
Att.Type x Vis.Field x Electrode	0.01	2	0.00	0.06	0.9403
Validity x Vis.Field x Electrode	0.01	1	0.01	0.12	0.7318
Att.Type x Val. x Vis.Field x Electrode	0.02	2	0.01	0.17	0.8470

Experiment 3: P2 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	15.72	1	15.72	5.59	0.0319*
Vis.Field	2.22	1	2.22	0.71	0.4136
Validity x Vis.Field	2.03	1	2.03	0.60	0.4509
Electrode	0.75	1	0.75	2.49	0.1357
Validity x Electrode	0.23	1	0.23	4.60	0.0488*
Vis.Field x Electrode	0.00	1	0.00	0.02	0.8917
Val. x Vis.Field x Electrode	0.00	1	0.00	0.05	0.8196

Experiment 3: P2 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	41.79	1	41.79	4.98	0.0414*
Vis.Field	6.49	1	6.49	2.65	0.1240
Validity x Vis.Field	2.85	1	2.85	1.45	0.2466
Electrode	1.58	1	1.58	2.02	0.1758
Validity x Electrode	4.02	1	4.02	19.85	0.0005*
Vis.Field x Electrode	0.02	1	0.02	0.19	0.6732
Val. x Vis.Field x Electrode	0.02	1	0.02	0.63	0.4395

Experiment 3: P2 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	5.94	1	5.94	2.50	0.1344
Vis.Field	1.64	1	1.64	0.60	0.4500
Validity x Vis.Field	0.50	1	0.50	0.36	0.5574
Electrode	3.50	1	3.50	18.53	0.0006*
Validity x Electrode	0.01	1	0.01	0.04	0.8452
Vis.Field x Electrode	0.00	1	0.00	0.05	0.8299
Val. x Vis.Field x Electrode	0.00	1	0.00	0.01	0.9421

Experiment 3: P300 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	219.06	2	109.53	10.47	0.0004*
Validity	29.63	1	29.63	5.13	0.0387*
Att.Type x Validity	35.23	2	17.61	3.92	0.0307*
Vis.Field	5.95	1	5.95	1.32	0.2678
Att.Type x Vis.Field	0.52	2	0.26	0.12	0.8894
Validity x Vis.Field	1.21	1	1.21	0.81	0.3820
Att.Type x Val. x Vis.Field	10.69	2	5.35	2.74	0.0811
Electrode	1.23	2	0.61	1.32	0.2812
Att.Type x Electrode	2.73	4	0.68	4.46	0.0032*
Validity x Electrode	0.35	2	0.17	2.49	0.0998
Att.Type x Val. x Electrode	0.26	4	0.07	0.72	0.5787
Vis.Field x Electrode	0.99	2	0.49	2.38	0.1099
Att.Type x Vis. Field x Electrode	0.33	4	0.08	2.06	0.0970
Validity x Vis.Field x Electrode	0.12	2	0.06	1.85	0.1753
Att.Type x Val. x Vis.Field x Electrode	0.27	4	0.07	1.35	0.2606

Experiment 3: P300 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	20.26	1	20.26	3.65	0.0756
Vis.Field	0.69	1	0.69	0.12	0.7317
Validity x Vis.Field	2.96	1	2.96	1.81	0.1980
Electrode	0.15	2	0.07	0.57	0.5707
Validity x Electrode	0.19	2	0.09	0.94	0.4024
Vis.Field x Electrode	0.33	2	0.17	1.69	0.2020
Val. x Vis.Field x Electrode	0.20	2	0.10	1.70	0.1998

Experiment 3: P300 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	42.14	1	42.14	8.37	0.0112*
Vis.Field	3.22	1	3.22	2.97	0.1056
Validity x Vis.Field	4.86	1	4.86	3.47	0.0821
Electrode	2.88	2	1.44	2.65	0.0872
Validity x Electrode	0.06	2	0.03	0.37	0.6916
Vis.Field x Electrode	0.03	2	0.02	0.16	0.8523
Val. x Vis.Field x Electrode	0.05	2	0.02	0.84	0.4409

Experiment 3: P300 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	2.45	1	2.45	0.59	0.4547
Vis.Field	2.57	1	2.57	1.14	0.3018
Validity x Vis.Field	4.08	1	4.08	1.72	0.2091
Electrode	0.94	2	0.47	4.77	0.0159*
Validity x Electrode	0.37	2	0.18	2.38	0.1101
Vis.Field x Electrode	0.95	2	0.48	5.13	0.0122*
Val.x Vis.Field x Electrode	0.14	2	0.07	1.57	0.2248

Experiment 3: N400 Amplitude; All attention types

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Att.Type	32.18	2	16.09	2.29	0.1189
Validity	0.12	1	0.12	0.06	0.8075
Att.Type x Validity	16.52	2	8.26	2.02	0.1504
Vis.Field	0.26	1	0.26	0.05	0.8238
Att.Type x Vis.Field	4.53	2	2.26	1.13	0.3375
Validity x Vis.Field	11.02	1	11.02	4.97	0.0415*
Att.Type x Val. x Vis.Field	6.83	2	3.41	1.32	0.2831
Electrode	1.92	2	0.96	1.23	0.3069
Att.Type x Electrode	0.49	4	0.12	1.54	0.2028
Validity x Electrode	0.06	2	0.03	0.35	0.7104
Att.Type x Val. x Electrode	0.31	4	0.08	1.52	0.2064
Vis.Field x Electrode	0.50	2	0.25	3.32	0.0496*
Att.Type x Vis.Field x Electrode	0.25	4	0.06	1.50	0.2132
Validity x Vis.Field x Electrode	0.25	2	0.13	2.73	0.0814
Att.Type x Val. x Vis.Field x Electrode	0.43	4	0.11	3.25	0.0177*

Experiment 3: N400 Amplitude; Social attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	0.15	1	0.15	0.04	0.8437
Vis.Field	0.09	1	0.09	0.03	0.8581
Validity x Vis.Field	16.18	1	16.18	8.80	0.0096*
Electrode	0.40	2	0.20	0.81	0.4523
Validity x Electrode	0.27	2	0.13	1.87	0.1715
Vis.Field x Electrode	0.17	2	0.08	1.52	0.2359
Val.x Vis.Field x Electrode	0.48	2	0.24	6.56	0.0043*

Experiment 3: N400 Amplitude; Voluntary attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	11.01	1	11.01	4.84	0.0440*
Vis.Field	4.01	1	4.01	1.52	0.2359
Validity x Vis.Field	0.32	1	0.32	0.13	0.7213
Electrode	0.18	2	0.09	0.31	0.7378
Validity x Electrode	0.08	2	0.04	0.65	0.5287
Vis.Field x Electrode	0.05	2	0.02	0.40	0.6735
Val.x Vis.Field x Electrode	0.10	2	0.05	2.16	0.1325

Experiment 3: N400 Amplitude; Reflexive attention only

ANALYSIS OF VARIANCE TABLE

SOURCE	SS	DF	MS	F	p
Validity	5.47	1	5.47	1.35	0.2628
Vis.Field	0.69	1	0.69	0.19	0.6732
Validity x Vis.Field	1.34	1	1.34	0.43	0.5219
Electrode	1.83	2	0.91	2.32	0.1160
Validity x Electrode	0.01	2	0.01	0.14	0.8677
Vis.Field x Electrode	0.53	2	0.27	5.89	0.0069*
Val.x Vis.Field x Electrode	0.10	2	0.05	0.97	0.3917

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