Your Attention, Please: The Competition and Comparisons between Social Cues in Directing Attention

A Thesis

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Abstract

Direction of eye gaze is known to be an important social cue for determining where others are attending, and there is also evidence that head direction may serve as a similarly effective cue. Previous experiments have studied the impacts of such social cues on detecting subsequent stimuli positioned at validly-cued versus invalidly-cued locations, suggesting that eye gaze and head direction are rapidly and implicitly processed with faster reaction times to validly-cued locations. Only a few studies have investigated the interaction of eye and head cues, e.g., when the eyes and head are in agreement versus in opposition to one another. There have been even fewer studies that have included neutral conditions, i.e., eyes and/or head directed straight forward, to examine facilitation versus inhibition of attention based on social cues. In order to systematically compare the influence of head and eye cues on spatial attention, the present study included all combinations of eye and head cues, as well as neutral cues, to determine how these social cues interact in guiding attention.

Participants were shown cues (9 different figures with the eyes and head directed in various combinations) followed by targets (Landolt Cs oriented either up or down) on a screen. They were tasked with identifying the orientation of the target gaps, and were informed that cue-target relationships were completely random, i.e., there was no advantage of attending towards the direction of the eyes and/or head cues. Reaction times and accuracy for the target discrimination task were measured and compared across conditions.

The results confirmed that eyes are indeed the most effective cue in directing attention—more so than the head—and that eye and head cues may essentially cancel each other out when incongruent, making performance in such conditions very similar to neutral ones. While not statistically significant, the results tentatively suggest both facilitation and inhibition of attention when valid and invalid cue conditions, respectively, were compared to neutral conditions. Head direction was not found to be a significant attentional cue on its own, but

the results suggest that it has some influence when acting in tandem with the eye cues.

Introduction

Attention Schema Theory

Attention is a selective process that facilitates the allocation of our mental resources to a subset of sensory stimuli, with the most relevant stimuli (or locations or features) being prioritized for further cognitive processing in order to flexibly guide our behavior. Attention is evolutionarily advantageous--both in terms of helping us avoid dangers and in forming and maintaining social bonds with others. Most broadly, attention shapes the ways in which we perceive and behave within our surroundings. Attention within a social context is particularly key to survival, e.g., observing where others are directing their attention can help us avoid threats and allow us to act accordingly in a variety of social situations. For example, if a threat appears outside our field of vision, we may be oblivious to its presence, but if another individual is present and *can* see the threat, being able to track the attention of the other individual will allow us to become aware of this danger too. Likewise, in a social situation we may be overwhelmed by various sights and sounds, but by being aware of the attention of those around us we can ascertain where it is most appropriate to direct our own attention. Social attention goes hand in hand with perceiving shifts in the behaviors of others, even going so far as to aid in the detection of deception and in predicting the intentions and future actions of others (Gerlofs et al., 2022). In this sense, having a well-developed awareness of social attention–or in other words, awareness of what others are attending to–is arguably of considerable importance to social species such as humans.

In order to account for this ability, not only to attend to stimuli, but to model the attention of ourselves and others, Graziano (2013) has developed a new hypothesis called the "Attention Schema Theory" (AST). This hypothesis states that we all have an attention schema, or an internal model that is descriptive of attention and allows us to make predictions about the behavior of ourselves and others. There is a close relationship between the things we attend to (versus ignore), and the likelihood of reacting to these things. Since there is a limited amount of attention available at any given time, if attention directed towards one item increases, attention directed towards other items must decrease (Graziano, 2019). Graziano posits that there are three heuristics that can be utilized to predict the focus of one's attention: gaze, or the direction in which someone is looking, salience, or how strongly something captures one's attention, and competition, or the degree to which one's attention may be taken away from one item in favor of another. Ultimately, he establishes the attention schema theory as something that grants individuals the ability to not only model the attention of oneself and others, but also to report the existence of a "self" who has an *awareness* of things to which it attends (Graziano, 2014). While related, attention is not synonymous with awareness, as attention is a physical process involving the dynamic interactions of neurons, electrochemical signals, and a variety of other tangible neural processes. In comparison, awareness (or more broadly, consciousness) is often described from the first-person perspective and is conceived of in much more nebulous ways, e.g., sometimes being referred to as "an insubstantial, internal essence" or a "ghostly feeling," similar to the concept of a non-material soul (Wilterson et al., 2020).

The attention schema theory operates under the assumption that there are three distinct phenomena enabled by our ability to model attention–the control of attention, certain aspects of social cognition, and our claims about having some kind of "subjective consciousness". In this model, the brain constructs an attention schema (a rough but useful caricature of attention) to efficiently understand, predict, and control attention while it is being directed to various stimuli. Such an attention schema is adaptive and will adjust accordingly to internal or external environmental changes, which allows it to be utilized to model the attentional states of other people, and in turn aid in predicting their behavior. Consciousness is another key aspect of the attention schema, which in this context is described as the brain's account of its own attention. However, attention and awareness remain two distinct conceptions, and thus attention may still remain--though control over it may be impaired--even when this consciousness or awareness via the attention schema theory is not present (Wilterson et al., 2020).

Gaze as a Heuristic for Attention

Perceiving what others are paying attention to is a ubiquitous implicit process in social situations, i.e., it happens all the time in an automatic fashion. Certain social cues, particularly those that are directional, can serve as primes and manipulate our attention towards a particular stimulus. For example, in a study conducted by Xu and colleagues (2018), it was found that participants were faster at identifying the location of face targets when they were facing directly towards, or making "eye contact" with, the participants. This is referred to as a "gaze-cueing" effect, in which information gleaned from the eyes (at least that which is supraliminal) cues our attention towards a particular location. According to Xu, this process occurs as a result of visual awareness, which allows one to detect and process the presence of eye contact and in turn stimulates attention (Xu et al., 2018).

It is widely recognized that gaze is a powerful indicator of attention, or more specifically, where attention is being directed. However, while observing gaze is an efficient and accurate measure of determining what is being attended to, gazing and attending remain two distinct processes, as it is quite possible for an individual to be looking at something while simultaneously (covertly) paying attention to something else entirely. In the attention schema theory, the human brain constructs a model of what it *means* to pay attention to something, whereas an eye tracker only registers that a person's eyes are pointed in a particular direction. Despite this key distinction, gaze does remain a helpful cue for identifying attention (Graziano, 2019). Given that solely tracking one's eyes is not an all encompassing assessment of attention, more information beyond that which is gleaned through the gaze is needed in order to better and more accurately assess not only what someone is currently attending to, but also what they are *going* to attend to.

Many studies establishing gaze as a heuristic for attention have been conducted, including a seminal study by Langton and Bruce (1999) in which they showed participants a face pointed in a particular direction for either 100 or 1000 milliseconds, which was then followed by the appearance of a target in a randomized location. The target was equally likely to appear in all four corners of the screen, but Langton and Bruce found that participants' reaction times were faster when the direction of gaze in the displayed face was aligned with the location of the target, indicating that the gaze of the figure cued participants to attend to the associated location. This correlation was only present in the 100 millisecond condition, supporting the notion of the automaticity of this type of attentional orienting. In other words, in the 1000 ms condition, attention may have quickly and automatically shifted in the direction of the cue, but then by the time the target appeared, the slower more voluntary control of attention was able to take over and allocate attention equally to both possible target locations (since the cues were non-predictive of the target locations). In sum, this study and others suggest that we make implicit assumptions surrounding what others are attending to based on their gaze, regardless of whether gaze and attention are actually aligned. However, Langton and Bruce also acknowledged that while gaze is certainly a powerful indicator of attention, it is important to not disregard other social cues that also contribute to our implicit modeling of others' attention. They argued that the heavy emphasis placed on gaze within previous studies has led to the neglect of other important cues, e.g., head direction, body posture, and hand gestures.

Direction-of-Attention Detector

A study conducted by Perrett and colleagues (1994) addressed some of these gaps, and identified that individual cells in the superior temporal sulcus (STS) region of the macaque temporal lobe are sensitive not solely to the orientation of our eyes, but to the conjunctions of eye, head and body. In examining these conjunctions, they found that the cells that are especially active when presented with downward looking eyes also react strongly when heads are directed downwards or when one adopts a quadrupedal posture, implicating the existence of an attentional intersection between these multiple social cues. Perrett also introduced the concept of a "direction-of-attention detector," also referred to as DAD, which combines the information obtained from analyzing the direction and position of the eyes, head, and body, and functions through a network of inhibitory connections (Perrett et al., 1994). Perrett found that of this information, that which is obtained from the eyes will override any other information that is provided by the head, and in turn, information that is provided by the head will override directional signals from the body. Rather than the eyes being the sole contributor to perception surrounding direction of attention, according to this proposal, there is a hierarchical relationship between eye, head, and body cues. While eyes occupy the top of this hierarchy, this does not discount the roles head direction and body language play in detecting the direction of someone else's attention. An additional study conducted by Lobmaier and Perrett (2011) was centered around attention and its relationship with facial expressions—particularly smiling faces. They found that when interpreting the direction smiling faces were attending to, participants more frequently perceived the faces as being directed towards themselves, as opposed angry or neutral faces, which were more often interpreted as directing their attention away from participants. This pattern was present when the whole face was displayed, but more importantly, also when the eyes were covered, implying that the information derived from the mouth and its associated facial expression was also powerful enough to impact perceived direction of attention. However, blocking out the eyes did make identifying the direction of attention a more difficult task, likely because gaze is capable of moving independently from the head, and thus when the eyes were not visible it was more unclear where attention was being directed. Lobmaier and Perrett theorized that the participants' bias for interpreting a happy face as attending to themselves was a result of this ambiguity. These results corroborate Perrett and colleague's (1994) previous findings, as information other than that from the eyes did impact perception of direction of attention, just not to the same extent that information from the eyes did.

However, more recent evidence suggests that the information gleaned from the direction of the head may not be suppressed when it conflicts with eye gaze direction, at least not as strongly as originally assumed. It was previously thought that this hierarchy of informative attentional cues was inhibitory, meaning that one cue would inevitably override the other, when in reality it may be that information from the eyes is just attenuating the efficacy of the head direction detector rather than eliminating it. If this holds true, it implies that even when the direction of the head and gaze are at odds, head direction still contributes some information to the computation of attention direction (Langton, 2000). Within this same study, Langton also found additional evidence that head and gaze cues are not mutually exclusive when it comes to indicating what is being attended to. In Langton's study, participants were presented with the same stimuli (multiple faces looking in different directions) and were asked to ignore these images when formulating their responses. Half of the faces were considered congruent, with the eyes and head directed in the same direction, and the other half were incongruent, with the eyes and head direction in opposition to one another. Participants were asked to respond as quickly and accurately as possible to either the gaze or head direction of said stimuli, and it was found that they had slower reaction times and less accuracy in incongruent conditions in comparison to congruent conditions. This held true in relation to responses to the heads of both up-down and left-right orientations, as well as responses to the up-down oriented gaze. Langton speculated that these results could potentially be attributed to the heightened discriminability of the direction of the gaze in incongruent as compared to congruent head direction trials. He also posited that they could be the result of participants judging gaze direction by using head direction as a frame of reference, or in other words, by perceiving gaze direction in terms of its relation to head direction.

In a follow up experiment, instead of solely using visual stimuli, participant responses were contingent upon a spoken directional word ("up", "down", "left" or "right"), which was presented simultaneously with each face. Upon hearing the word "up," participants were able to produce quicker responses when the gaze and head of the figure were both directed upwards as compared to when they were directed downwards. Yet when the direction of the head was in opposition to the direction of the eyes, this congruency effect was eliminated entirely. These results imply that information from both gaze and head direction is utilized when generating responses, even in instances where participants are attempting to ignore these attentional stimuli. Furthermore, when placed in conflict, the information gleaned from head direction is sufficient to overcome the information gained from an incongruently directed gaze. Holistically, these findings indicate that, when it comes to computing attention direction, the head and gaze are more equivalent than Perrett had initially thought when constructing his DAD model, which posits that any information obtained from the head will be overridden by the direction of eye gaze (Perrett et al., 1994).

Attentional Eye and Head Cues

Further support for the influence of head direction on the directing of attention can be found in a study conducted by Maruyama and Endo (1983), in which eye and face patterns with moveable irises were presented and participants reported their perception of the direction of the figures' gaze. Unlike previous studies, they found that when the eye and head direction was incongruent and the eyes were met with the "towing force" of the face, the perceived direction of gaze in the figures fell somewhere between the eyes' genuine gaze direction and the figures' head directions. In fact, the pulling force of the face frame seemed to have more influence on perceived gaze than the direction of the eyes themselves, as this perceived gaze intermediate, or where participants believed the figures' gaze to be, tended more toward the direction of the head than that of the eyes. These findings thus provide further evidence that the perceived direction of attention is determined not solely by the eyes, but is a result of the *interaction* between the direction of both the eyes and the head.

In addition to both head and gaze cues interacting to influence attention, it has also been argued that these cues to direction (in addition to hand cues) are processed automatically and in parallel in order to generate directional decisions. This concept was explored within a study conducted by Langton and Bruce (2000), where they posited that we automatically analyze head, gaze, and hand cues (specifically pointing gestures) because such directional signals are processed as cues that can detect the direction of others' social attention. In order to support this notion, they conducted a stroop test that displayed head-gaze cues as well as pointing gestures and spoken directional words, which participants were instructed to ignore. They found that reaction times were slower when the gesture and voice were incongruent, and that the congruency effect was largest when the head direction was in agreement with the direction of the gesture (as compared to any neutral head orientation or orientations in which the head direction was not in agreement with the direction of the gesture). Through conducting this stroop test they observed an interference effect, implying that the dimension that is intended to be ignored is not only automatically processed, but is automatically processed in conjunction with the information encoded from the target dimension (the dimension that is intended to be attended to). Next, they asked participants to press particular keys based on the direction of gesture in one block of trials and based on the direction of the head in a separate block. They claimed that if these two distinct cues are indeed processed in parallel, then the effects seen in both blocks of trials should be symmetrical; Responses to gestures should be impacted by head cues that are intended to be ignored, and responses to head cues should be impacted by irrelevant pointing gestures in a similar fashion. Langton and Bruce did ultimately find such bidirectional effects, though they were not symmetrical, as responses to head direction were more impacted by irrelevant gestures than vice versa. While irrelevant directional head cues are somewhat lacking in discriminability, Langton and Bruce ultimately established that in spite of this, they still elicit interference effects when interacting with pointing gestures, which are considerably more discriminable.

In a separate study, Langton and Bruce (1999) also explored the exogenous and endogenous processing of attentional cues, with exogenous orienting benefiting target detection at shorter stimulus onset asynchronies (SOAs)--the interval between the appearance of the cue and the target–and the endogenous mechanism benefiting target detection at longer SOAs. They began by having participants press a series of keys in response to detecting a target letter which was equally likely to appear on all sides of the fixation. This was then followed by a precue that consisted of a head directed towards one of these possible target locations, and in the first of a series of experiments, these head precues correctly produced the location of the targets on 50% of the trials. Given this percentage, any improved target detection at cued locations (in comparison to uncued locations) would be representative of a reflexive or exogenous process that redirects attention based on the location aligned with the precue. Langton and Bruce obtained faster reaction times when the location of the target was in agreement with the precue at the 100 millisecond stimulus onset asynchrony (SOA), which is further evidence that there exists such an exogenous orienting mechanism that reacts automatically and reflexively to head direction precues. In a follow up experiment, Langton and Bruce altered their study design such that one cued location was now three times as likely to contain a target than any one of the other three uncued locations, and additionally instructed participants to focus on the cues. They posited that if the advantage for target detection at cued over uncued locations in preceding experiments was the result of an orienting process that was entirely exogenous in nature, then participants' knowledge should not impact the results of the experiment. As a result of these new experimental conditions, a precuing effect was induced at the 1000 millisecond SOA in addition to the initial 100 millisecond SOA. As a whole, these findings suggest that head precues are able to engage not only exogenous orienting mechanisms, but endogenous orienting mechanisms as well.

The Present Study

Within this body of literature there is abundant evidence that gaze plays a vital role in interpreting the object or direction of one's attention, as well as consistent experimental results that other body gestures—particularly head direction—also participate in this perception of attention. However, there remains a dearth of knowledge when it comes to examining left-right head direction, as previous studies have found the most dramatic results within up-down orientations and as a result have opted to focus almost exclusively on that dimension. Langton (2000) even found that the results he obtained when examining the up-down orientation did not replicate in the left-right orientation, which may be indicative of something fundamentally distinct about the left-right orientation from the up-down orientation. Likewise, perhaps the lack of a congruency effect found in the left-right orientation was a result of a less drastic or more ambiguous difference in directionality than in the up-down orientation. In terms of previous relevant studies, Langton and Bruce (2000) found a congruency effect—meaning that participant reaction times were faster when head and gazes were in agreement as opposed to in opposition—through the use of a stroop test. However, it remains unknown whether these results would translate to another method of assessing attention, such as the Posner task. In the context of social attention, the (exogenous version of the) Posner task involves presenting a figure with various combinations of head and gaze directions, which briefly flash upon a screen and are followed by a target that is equally likely to appear on either side of the figure (Posner, 2016). Such a task is intended to demonstrate that social cues induce automatic shifts in attention, as theoretically the reaction time for identifying the target should be faster when it appears in the location that was cued via the direction of gaze and/or the head. Additionally, even though participants are aware that attending to the direction of the cue is not at all advantageous in terms of locating the target (it is equally likely to appear in any location regardless of what has been cued), this phenomenon persists, corroborating the claim that paying attention to and deriving information from directional social cues is a process that occurs automatically.

In addition, while several experiments have been centered around congruent versus incongruent cues, there has been relatively little examination of neutral conditions (i.e., gazing or having one's head pointed directly forwards, when the targets appear at peripheral locations), or trials in which the addition of a neutral condition prevents the eyes and head from being entirely opposed or aligned with one another. Adopting such neutral conditions and combinations of neutral and directional conditions allowed for a more systematic assessment of attentional cues, and provided insight into which specific combinations of head and eye cues were most—and least—efficient and accurate in terms of guiding attention. To this effect, I sought to answer the following question: How do various social cues compete and interact with one another when influencing our modeling of attention, and are some of these cues automatically prioritized over others or processed in parallel? I hypothesized that the eyes valid / head valid condition would lead to the fastest reaction times, while the eyes valid / head neutral condition and the eyes neutral / head valid condition would both result in faster reaction times compared to the eyes neutral / head neutral condition. Additionally, I hypothesized that while the effect may be small, the eyes valid / head invalid condition as well as the eyes invalid / head valid condition would result in somewhat impaired reaction times in comparison to the eyes neutral / head neutral condition, while still leading to faster reaction times than the eyes invalid / head invalid condition.

Methods

Participants

A total of 31 participants (11 female, 14 male, 3 non-binary, 3 non-specified; 18-22 years, mean = 20.4 years, SD = 1.23 years; 26 white non-Hispanic, 4 Asian, 1 Latinx; 27 right-handed, 4 left-handed) were recruited via flyers and online postings at Reed College in Portland, Oregon. One participant was excluded due to failing to meet the 70% accuracy threshold in the target discrimination task (final analyzed sample: N = 30). All participants had visual acuities of 20/40 or better, which was tested using a Snellen eye chart. Participants were given the opportunity to enter a lottery to win $50, with participants earning one lottery ticket per 20 minutes of participation and one ticket being drawn per every 15 tickets entered. All procedures were approved by the Reed College Institutional Review Board.

Equipment

The experiment was conducted using a BenQ monitor with 1920 x 1080 resolution and 120Hz framerate. The programming of the experiment and recording of data was done on Presentation (Neurobehavioral Systems), and participants pressed the left and right keyboard keys to indicate their responses within the trials. The data was then analyzed in MATLAB (MathWorks) with some of the statistical tests being conducted in JASP (University of Amsterdam).

Stimuli

The stimuli fell under two categories: cues and targets. The cues consisted of 9 distinct figures, each of which displayed a woman's face with her head and eyes oriented in a variety of combinations. The combinations were as follows (the term after the word “head” or “eyes” referring to their respective direction, where “neutral” signifies a forward-facing head and/or eyes).

:

Eyes right / head neutral
Eyes neutral / head neutral
Eyes left / head neutral
Eyes right / head right
Eyes neutral / head right
Eyes left / head right
Eyes right / head left
Eyes neutral / head left
Eyes left / head left

As the targets were presented on either the left or right (50% probability), this led to 18 total conditions when considering cue-target combinations. After compiling the data, left and right target locations were collapsed, and cue-target validity versus invalidity was examined, with validity and invalidity being defined as the eyes being directed towards (valid) or away (invalid) from the target. The figures were then collated into the following combinations of head and eye cues with respect to the location of the Landolt C targets.

:

Eyes neutral / head neutral
Eyes valid / head neutral
Eyes invalid / head neutral
Eyes neutral / head valid
Eyes neutral / head invalid
Eyes valid / head valid
Eyes invalid / head invalid
Eyes valid / head invalid
Eyes invalid / head valid

Figure 1. Head and eye cue combinations.
A 5 x 8 cm face (not to scale) 0.7 m away from the monitor (visual angle = 4.09 x 6.54 °) with 9 distinct head and eye combinations that are oriented to the right, straight forward (neutral in terms of the relationship with the left/right targets), and to the left.

The targets consisted of Landolt Cs, which are Cs of various sizes and orientations with gaps that can also have various sizes and orientations (Kröger et al., 2017). For the purposes of my experiment, I only used Landolt Cs with gaps that are oriented exclusively up or down, and the gap width was determined during pilot testing to ensure a challenging enough discrimination task but without being impossibly challenging.

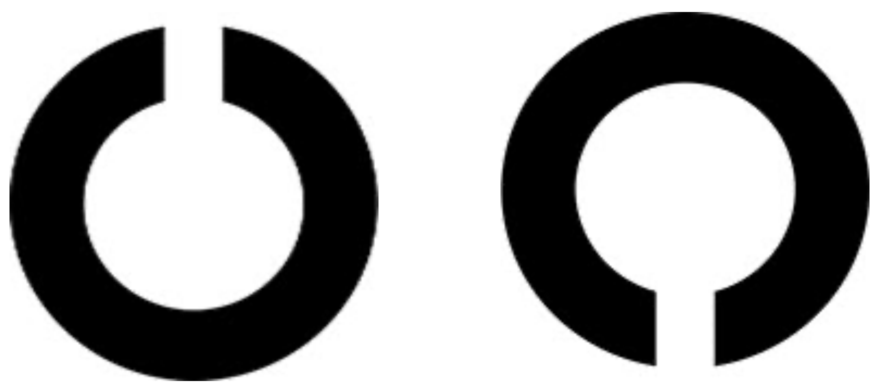

Figure 2. Landolt Cs.
Two 5 x 5 cm Landolt Cs (not to scale) oriented either up or down (visual angle = 4.09 x 6.54 °). These Cs were presented at 9.8 ° eccentricity in the periphery on either the left or right side of the cues.

Procedure

Prior to administering the experiment, participants' visual acuity was assessed via a Snellen eye chart. If they were proven to have a visual acuity of 20/40 or better, they were permitted to proceed with the experiment. Participants were instructed to fixate on the center of the screen, and to press the left key if they observed the target gap as facing upwards, and the right key if it was facing downwards. They were informed that the direction of the cue had no correlation with where and in what orientation the target would appear, and that there was no statistical advantage in directing their attention towards the location that was being cued.

Participants were seated 0.7 m away from the monitor, but were permitted to move the keyboard however close or far from their body as they pleased. They were instructed to look directly at the monitor, where a fixation dot would appear for 1500 milliseconds, followed by the cue in the center of the screen for 50 milliseconds, a blank screen for 50 milliseconds, and then one of the targets until the left or right key was pressed. The cues were equally likely to be displayed as any one of the 9 combinations, and the targets were equally likely to appear on the left and right of the cue, as well as equally likely to have the gap in the C in the upwards or downwards orientation.

Before undergoing the actual experiments, participants were required to complete 45 practice trials and were granted breaks every 5 minutes. They then completed a total of 360 experimental trials, with 4 blocks within this total and 90 trials per block. These trials were split up such that there were 40 trials for each of the 9 cue conditions, and within each block there were 10 trials per condition for all of the target orientations (to the left of the cue with an upwards facing gap, to the left of the cue with a downwards facing gap, to the right of the cue with an upwards facing gap, and to the right of the cue with a downwards facing gap).

After the end of the experimental portion of this study participants were asked to fill out a demographic survey to determine the breakdown of age, gender, race/ethnicity, and handedness within the study's population.

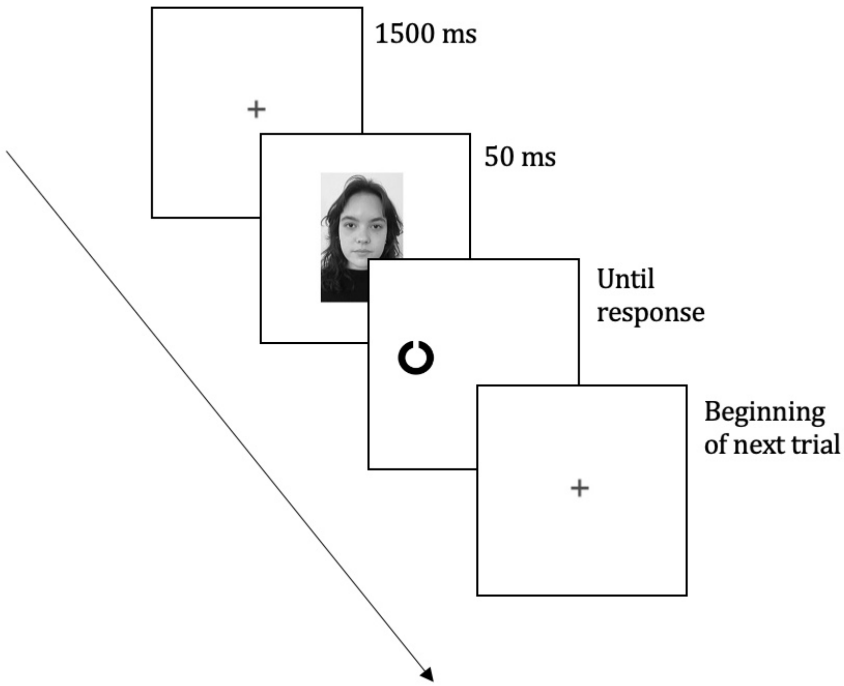

Figure 3. Example trial.
A fixation cross flashed on the screen for 1500 ms, followed by the cue in the center of the screen for 50 ms. Next, the target appeared on the screen until participants pressed either the left or right key, and then the next trial began and the pattern was repeated.

Exclusion Criteria

Participant data was excluded from analysis on account of a predetermined performance threshold and a valid response reaction time range. An entire subject's data set was excluded if their performance on the discrimination task was below 70% accuracy, and individual trials were excluded if they took less than 200 or more than 1000 milliseconds to respond. A participant's data for any given condition was considered an outlier and excluded if their average reaction time was greater than 2 standard deviations away from the mean.

Results

Reaction times (msec) were measured as the time between target onset and the pressing of the right or left arrow keys. The means and standard deviations of reaction times were calculated and graphed in MATLAB. Right and left dimensions of the cues and up and down dimensions of the targets were both collapsed during data analysis. Depending on the particular question, dependent samples t-tests and/or repeated measures ANOVAs were used to assess differences in reaction times across conditions. In the results figures, E stands for eye cues, H for head cues, and the + symbols represent valid, - symbols represent invalid, and "n" represents neutral conditions for a given cue. For example, E+H- represents the eyes valid / head invalid condition.

Effects of Eye and Head Cues in Isolation

First, to assess the influence of eye cues and head cues alone, two separate one-way ANOVAs, each with 3 levels (valid, neutral, invalid), were conducted while keeping either the head or eyes neutral. These ANOVAs were followed up with paired t-tests. There proved to be no statistically significant differences in reaction times between the eyes neutral / head neutral condition versus any of the other conditions, although numerically, the eyes neutral / head neutral condition led to reactions times intermediate to the valid and invalid comparison conditions. However, there was a significant difference between eyes valid / head neutral versus the eyes invalid / head neutral condition when comparing these conditions directly ($M = 672.8$, $SD = 63.5$), $t(29) = -2.154$, $p = 0.033$ (Figure 4), confirming the cue validity effect for the eyes. No significant main effects were found in either of the ANOVAs, nor between any other conditions in the paired t-tests, including the eyes neutral / head valid condition versus the eyes neutral / head invalid condition (Figure 5).

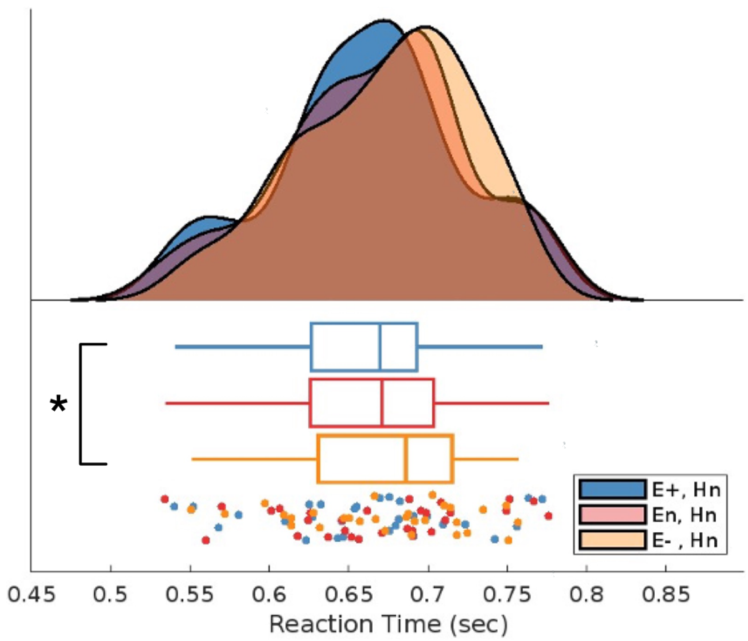

Figure 4.
Reaction times for conditions with head neutral. The top panel shows the distribution of reaction time among participants, the box plots show the median reaction times, and the whiskers show the range of reaction times. Each dot below the bar and whisker graphs represents a participant. The bracket with an asterisk represents the relationship that is statistically significant.

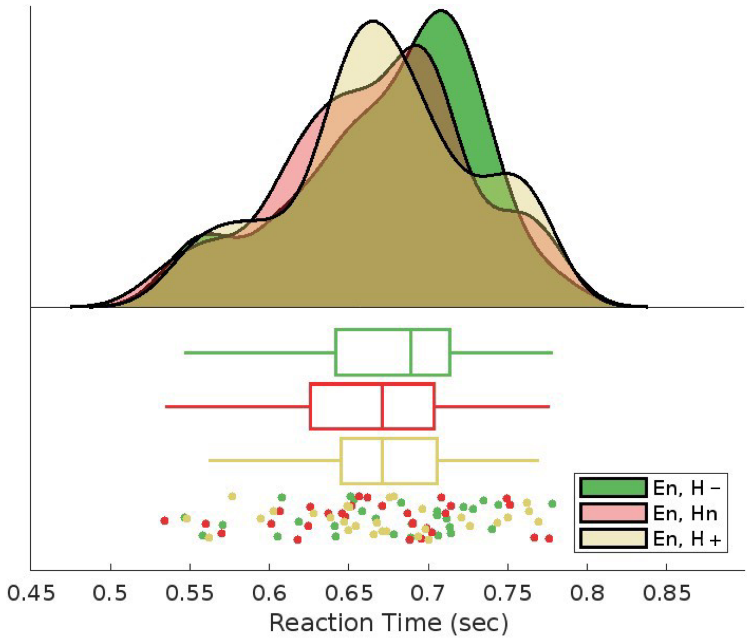

Figure 5.
Reaction times for conditions with eyes neutral. The top panel shows the distribution of reaction time among participants, the box plots show the median reaction times, and the whiskers show the range of reaction times. Each dot below the bar and whisker graphs represents a participant.

Eye and Head Cue Validity Interactions

A 2x2 repeated measures ANOVA, with the factors eye validity (valid/invalid) and head validity (valid/invalid) did not reveal any significant main effects or interactions, but there was a trend towards a main effect of eyes ($F = 2.772$, $p = 0.110$) and a main effect of head ($F = 2.328$, $p = 0.138$) with no interaction between the two types of cues ($F = 0.102$, $p = 0.752$). None of the pair-wise t-tests showed significant differences except for the eyes valid / head valid ($M = 664.0$, $SD = 64.5$) versus the eyes invalid / head invalid condition ($M = 673.3$, $SD = 69.5$), $t(29) = -1.955$, $p = 0.050$ (Figure 6 & 7).

In a follow-up exploratory analysis, significant differences in reaction times were also found between both the eyes valid / head neutral ($M = 662.6$, SD

= 67.4) condition versus the eyes invalid / head invalid condition (M = 673.3, SD = 69.5), t(29) = - 2.063, p = 0.041, as well as between the eyes neutral / head valid condition (M = 674.8, SD = 66.2) versus the eyes valid / head valid condition (M = 664.0, SD = 64.5), t(29) = 2.913, p= 0.004.

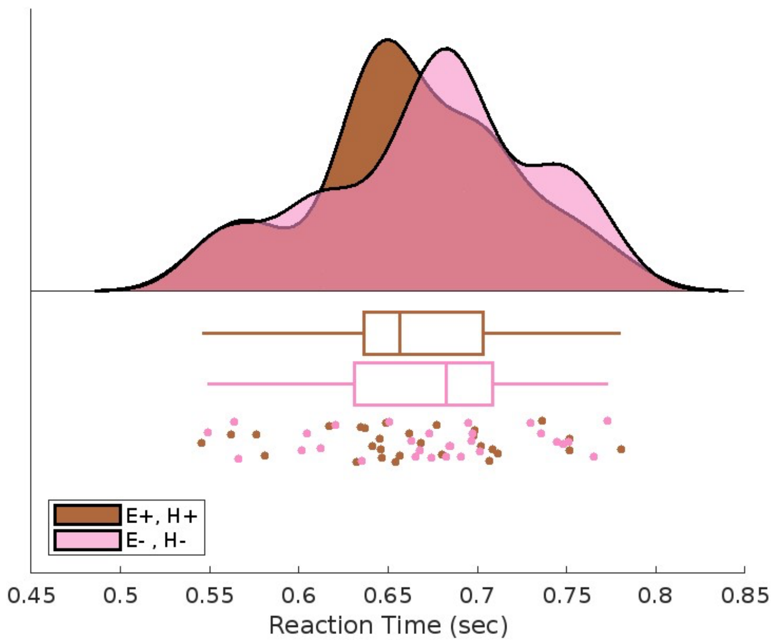

Figure 6.

Reaction times for eyes valid / head valid versus eyes invalid / head invalid conditions. The top panel shows the distribution of reaction time among participants, the box plots show the median reaction times, and the whiskers show the range of reaction times. Each dot below the bar and whisker graphs represents a participant.

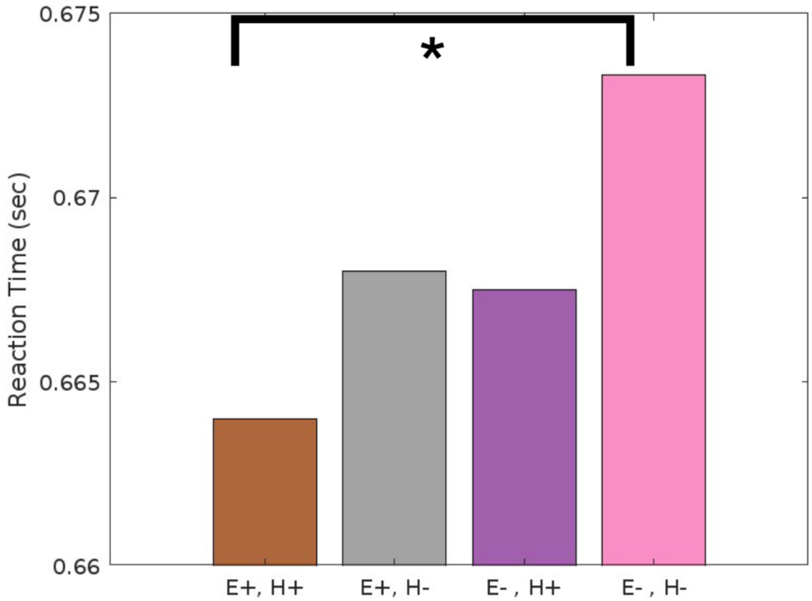

Figure 7.
Average reaction times for the eyes valid / head valid, eyes valid / head invalid, eyes invalid / head valid, and eyes invalid / head invalid conditions. The bracket with an asterisk represents statistically significant differences between conditions.

Direct Comparison of Eye and Head Cues

To directly compare eye and head cues while holding the other cue constant, the eyes valid/ head neutral condition was compared with the eyes neutral / head valid condition (Figure 8), and in addition, the eyes neutral / head invalid condition was compared with the eyes invalid / head neutral condition (Figure 9). There proved to be differences between the reaction times for the eyes valid / head neutral condition ($M = 662.6$, $SD = 67.4$) versus the eyes neutral / head valid condition ($M = 674.8$, $SD = 66.2$), $t(29) = - 2.850$, $p = 0.005$ (Figure 8), with the eyes serving as a stronger attentional cue, leading to faster reaction times compared to the head.

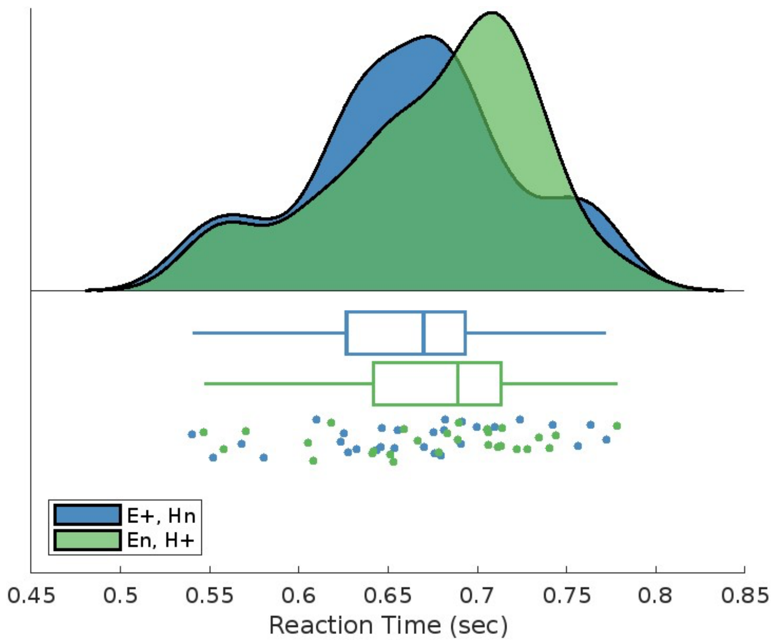

Figure 8.
Reaction times for eyes valid / head neutral versus eyes neutral / head valid conditions. The top panel shows the distribution of reaction time among participants, the box plots show the median reaction times, and the whiskers show the range of reaction times. Each dot below the bar and whisker graphs represents a participant.

There was no significant difference in reaction times between the eyes neutral / head invalid (M = 670.9, SD = 68.0) versus the eyes invalid / head neutral conditions (M = 672.9, SD = 63.5), t(29) = -0.481, p = 0.631 (Figure 9), though the eyes neutral / head invalid condition did trend towards faster reaction times, i.e., in the expected direction for this contrast.

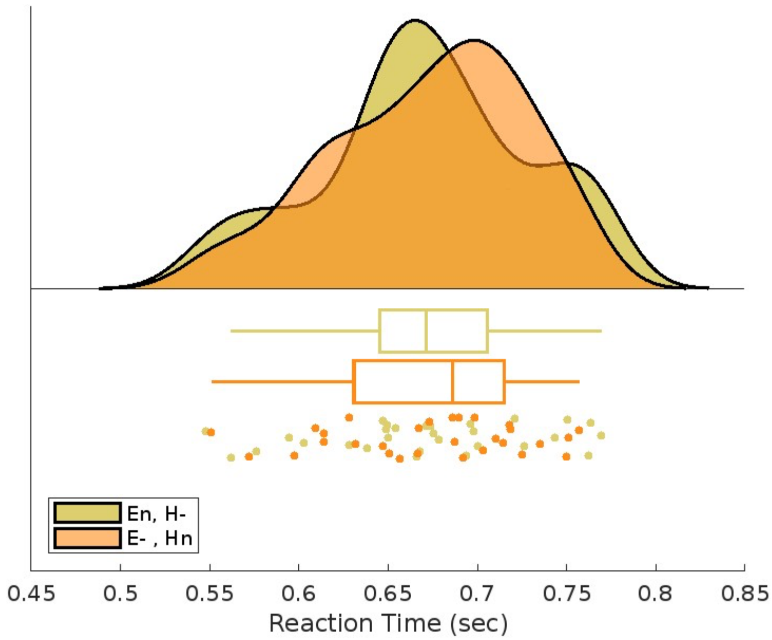

Figure 9.
Reaction times for eyes neutral / head invalid versus eyes invalid / head neutral conditions. The top panel shows the distribution of reaction time among participants, the box plots show the median reaction times, and the whiskers show the range of reaction times. Each dot below the bar and whisker graphs represents a participant.

Accuracy

There were no statistically significant differences between the accuracies of any of the conditions, with the 75th percentile representing 100% accuracy (Figure 9).

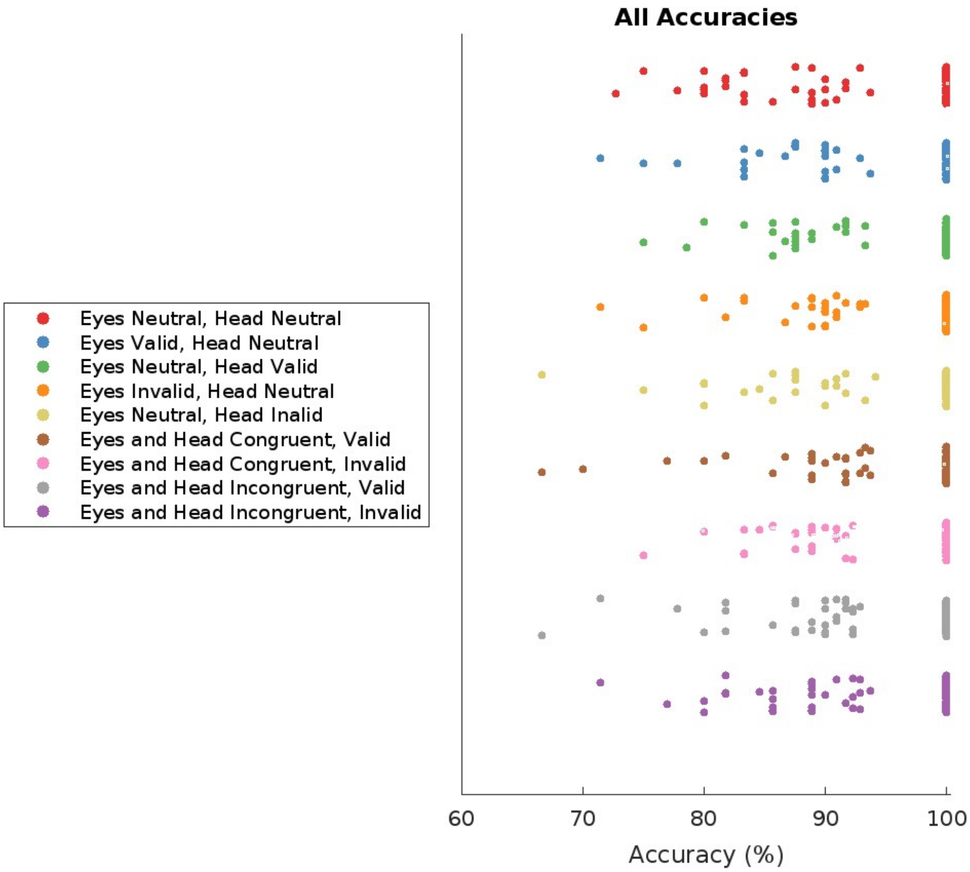

Figure 9. Raincloud plots of % accuracy across all conditions. Each dot represents a participant for each of the given conditions.

There were also no statistically significant differences in accuracy between the eyes neutral / head valid (M = 97.5%, SD = 5.5%) versus the eyes valid / head neutral (M = 97.1%, SD = 6.0%) conditions, t(29) = 0.560, p = 0.577 (Figure 10), or between the eyes valid / head valid (M = 97.0%, SD = 6.2%) versus the eyes invalid / head invalid conditions (M = 97.3%, SD = 5.5%), t(29) = -0.442, p = 0.659 (Figure 11), despite these comparisons being the most significant in terms of reaction times.

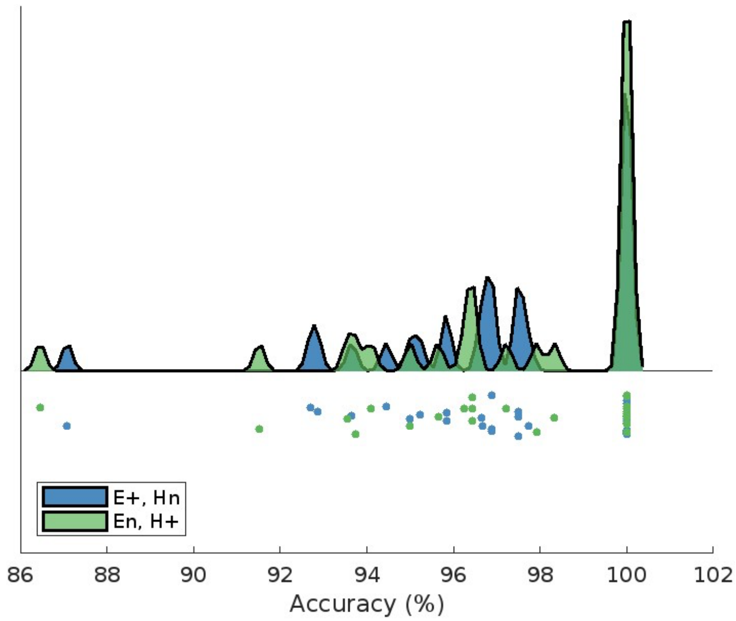

Figure 10.
Raincloud plots of % accuracy for conditions with eyes valid versus conditions with head valid. The top panel shows the distribution of reaction time among participants, and each dot represents a participant.

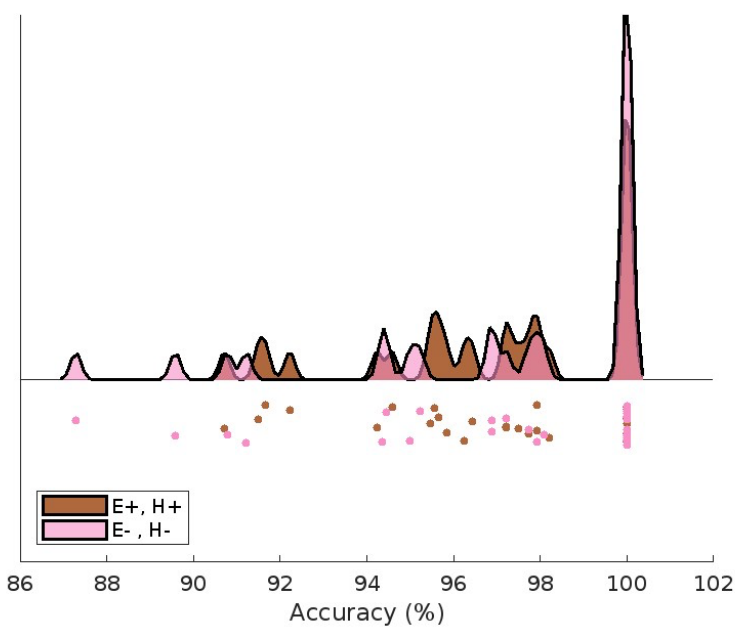

Figure 11.

Raincloud plots of % accuracy for conditions with eyes valid / head valid versus conditions with eyes invalid / head invalid. The top panel shows the distribution of reaction time among participants, and each dot represents a participant.

Discussion

Summary of Results

In the present study, I presented participants with 9 distinct cues (figures with various combinations of eye and head directions) on the center of a screen and measured the time it took for them to identify the target (the Landolt C) depending on which combination of cues preceded it. I also assessed their accuracy when it came to identifying the orientation of the target, and compared both reaction times and accuracies between the varying target and cue combinations. The cues were intended to direct participants' attention towards either the left or right of the screen, and thus measuring the reaction time between onset of the target and the response identifying the target orientation (marked by pressing either the left or right key) provided insight into which cues were most effective in doing so.

The results indicated that there were significant differences between the following conditions, and no differences in accuracy were found across all conditions.

:

Eyes valid / head neutral (eyes pointing towards the C) vs
eyes invalid / head neutral (eyes pointing away from the C)

Eyes valid / head valid (eyes and head both pointing towards the C) vs
eyes invalid / head invalid (eyes and head both pointing away
from the C)

Eyes valid / head neutral (eyes pointing towards the C) vs
eyes invalid / head invalid (eyes and head both pointing away
from the C)

Eyes neutral / head valid (head pointing towards the C) vs eyes valid / head valid (eyes and head both pointing towards the C).

Eyes valid / head neutral (eyes pointing towards the C) vs eyes neutral / head valid (head pointing towards the C)

Direct Comparison of Eye and Head Cues

According to my results, there exists a significant relationship between multiple neutral eye and head conditions, with the condition consisting of valid eyes always yielding a faster reaction time. Holding the head neutral and having the eyes be valid had a larger impact on reaction time (trending towards faster times) than holding the eyes constant and having the head be valid, implying that eyes are a more powerful towing force than the head when it comes to capturing attention. Assigning the head to be neutral allowed the impact of eye direction on attention to be measured in isolation (and vice versa with the eyes being neutral and the impact of head direction being measured), as there was no interference from the other directional dimension. Thus, the fact that the reaction time was faster when the eyes were valid supports the claim that eyes are more effective in directing attention than the head. These results also indicate that it was primarily the towing force of the eyes that was responsible for the observed difference in reaction times, and that any interference from the head was not a necessary requisite for effectively directing attention. In sum, when the head was held neutral, the eyes were a strong enough director of attention to improve reaction times, but the same could not be said for the head when the eyes were held neutral. In addition, while the relationship was not significant, the eyes neutral / head invalid condition trended towards yielding faster reaction times that the eyes invalid / head neutral condition, which also supports the notion that the eyes are more integral to the process of directing attention than the head. Such a relationship implies that establishing the eyes as invalid hinders reaction time more so than when the head is invalid, and that perhaps even having the head oriented in a neutral direction is enough to at least somewhat counteract the effects of the invalid head direction. However, as was the case with the previous comparison between conditions, when this dynamic is reversed, the neutral direction of the head does not have the ability to speed up reaction time when pitted against the invalid eye direction.

Eye and Head Cue Validity Interactions

This same relationship was present within the relationship between the eyes valid / head valid condition versus the eyes invalid / head invalid condition, with the eyes valid / head valid condition yielding faster reaction times than the eyes invalid / head invalid condition. Such a relationship once again supports the notion that the eyes are incredibly influential in terms of our orienting of attention, as participants noticed the target faster when the eyes of the figure had previously pointed towards where it appeared on the screen. It may seem intuitive that the reaction time of the condition where the eyes and head were both directed towards the C would be faster than that of the condition where they were directed away from it, but in actuality it is also a clear indicator that the experimental paradigm is functioning properly—It would be a cause for concern if the invalid condition elicited faster reaction times, or even if there were simply no difference in reaction times at all.

Amongst the conditions with cues either in complete alignment or opposition to one another, I hypothesized that the eyes valid / head valid condition would result in the fastest reaction times, followed by the eyes valid / head invalid condition, then the eyes invalid / head valid condition, and lastly the eyes invalid / head invalid condition. While my predictions for which conditions would result in the fastest and slowest reaction times held true, the eyes invalid / head valid condition actually produced faster reaction times than the eyes valid / head invalid condition. However, the difference between these two conditions was not significant and thus no decisive conclusions can be drawn, but this data does point towards the head potentially playing at least a minor role in the directing of attention.

In terms of exploratory analyses, the relationship between the eyes valid / head neutral versus the eyes invalid / head invalid conditions (which did prove to be significant) operates on the same principle as the eyes valid / head valid versus eyes invalid / head invalid condition. Reaction times were consistently faster when the target was aligned with the orientation of the cue (particularly the eyes)—when it was valid—than when the cue orientation was in opposition to the direction of the target—when it was invalid. This phenomenon held true across the large majority of conditions, with the primary exception being comparisons made with cue orientations in which the eyes and head were in opposition, which seemingly involved both the eyes and head vying for attention and subsequently nullifying one another. In contrast, eyes valid / head valid cues should theoretically lend themselves towards faster reaction times, as multiple attentional cues—not solely the eyes—direct attention to the same location. The eyes alone remained a powerful director of attention, even without any influence or interference from the head, though it is possible that the head worked in tandem with the eyes to direct attention towards the target location. If this holds true, it is also possible that the head may have strengthened the already present attention capturing abilities of the eyes and made this effect even more dramatic, despite the fact that the head in isolation was not powerful enough to elicit such a shift in reaction times.

There was also a significant difference in reaction times between the conditions with eyes neutral / head valid versus eyes valid / head valid, with the latter inducing faster reaction times. As was the case when comparing the previous two conditions, the fact that the eyes were much more effective directors of attention than the head also made this result seem logical and relatively straightforward. However, If the head genuinely does interact with and strengthen the already impressive impact of the eyes on our modelling of attention, this interaction would provide insight into what factors truly make the eyes valid / head valid condition so effective in capturing attention.

Partial Support for the Direction-of-Attention Model

None of the differences in reaction times between head valid / invalid conditions proved to be statistically significant, providing further evidence that it is the eyes, not the head, that are capable of redirecting attention. These results potentially support Perret's direction-of-attention-director (DAD) model, which operates on the assumption that any information obtained from the eyes will trump that from the head (which will then override signals from the rest of the body) in a hierarchical fashion (Perrett et al., 1994). The central idea of the model is that eyes are not the only functioning mode of perceiving and altering directional attention, and that other cues from the head and body also play a role, albeit a smaller one than the eyes. According to Perrett, the hierarchical relationship between these cues does not devalue the role of the head and body in the detection of the direction of attention, as in the absence of information provided by the eyes, cues from the head will take over and participate in the process of detection.

The results of this experiment indeed support the notion that eye cues take precedence over head cues, though they diverged from the DAD model when it came to how significant (or rather, insignificant) the impact of head cues was when eye cues were no longer present. There were no statistically significant differences between head valid conditions (head pointing towards the C) versus invalid conditions (head pointing away from the C)--even in the conditions where the eyes were neutral and held constant—which implies that the direction of the head did not impact the reaction time for identifying the targets. Since the eyes were in a neutral orientation and therefore did not participate in any attentional cueing, any differences in reaction time between valid and invalid conditions could only have been a result of directional information provided by the head. Thus, the lack of significant differences in reaction times between head valid and invalid conditions (when eyes were held neutral) can be attributed to the head's inability to direct attention towards any particular direction.

According to these results, the eyes are not merely prioritized over the head when directional stimuli is being perceived, but the influence of the head in informing the direction of attention is eliminated entirely—or rather, it may not have existed in the first place. However, a differing interpretation is that the head *does* have an influence, but exclusively when acting in tandem with the eyes. This perspective is supported by the fact that the eyes valid / head valid and eyes invalid / head invalid conditions induced the fastest and slowest reaction times, respectively, with the other combinations falling numerically in between. These conditions did not only rely upon the eyes as being in alignment with or in opposition to the target in order to impact reaction time, as the head was not held neutral, and thus it can be assumed that it was an active participant in the directing of attention. The head was evidently not capable of effectively capturing attention in isolation, but the fact that the eyes valid / head valid and eyes invalid / head invalid conditions produced the fastest/slowest reaction times indicated that the influence the eyes had over orienting attention was likely *strengthened* by the head.

The Division of Attention between Eye and Head Cues

There were also no statistically significant differences in reaction times between the eyes valid / head invalid condition (eyes pointed towards the C and head pointed in the opposite direction) and eyes invalid / head valid condition (eyes pointed away from the C and head pointed in the opposite direction). While this is merely speculative, these results could be a product of head and eye direction essentially canceling each other out, thus making a condition in which the head and eyes are in opposition--the eyes valid / head invalid condition as well as the eyes invalid / head valid condition--no different from a neutral one. With attention being divided between the eyes and head—which in this case were oriented in opposite directions--it may have become difficult to hone in on one particular directional cue, and as a result attention could have been directed towards a middle ground between the two cue orientations. Valid and invalid conditions were irrelevant in the context of the conditions in which both the head and eyes were neutral, as it was impossible for the eyes nor the head of the cue to be pointing toward the location in which the target would appear. Thus, if the incongruent cue orientation functioned and produced results very similar to those of the completely neutral condition, there would then be no expected difference in reaction times amongst conditions that fell under the eyes valid / head invalid or eyes invalid / head valid categories. These two conditions forced attention to be divided between both directions, preventing either one of them from being fully attended too, and in turn inducing no reduction in speed. This still held true in the instances where the eyes—which have previously been observed as a powerful director of attention--were directed towards the target, which only further emphasizes the strength of cue incongruence in dividing attention amongst multiple directions.

Discriminability between Eye and Head Cues

In addition to having no statistically significant differences between the eyes valid / head invalid versus eyes invalid / head valid conditions, within this experiment there were also no statistically significant differences between any of the conditions in which the eyes and head were in total alignment or opposition, regardless of validity status. This lack of significant results surrounding the eyes valid / head valid and the eyes invalid / head invalid conditions versus the eyes valid / head invalid and the eyes invalid / head valid conditions did not support the results of Langton's study, in which, much like the current experiment, reaction times and accuracies for congruent versus incongruent head and eye orientations were recorded and compared (Langton, 2000). He found that participants had both poorer reaction time and accuracy in trials in which the eyes and head were in opposition versus trials in which they were in agreement, and proposed that this may be due to the high levels of discriminability—or the degree to which one stimulus can be perceived differently from another—between head and eye orientations.

The present study also supported the notion of heightened discriminability, though its results seemed to suggest that this discriminability produces the opposite effects as those observed by Langton. As there were no significant differences between the reaction times of the eyes valid / head valid and the eyes invalid / head invalid conditions versus the eyes valid / head invalid and the eyes invalid / head valid conditions, it can be concluded that, if discriminability within the eyes valid / head invalid and the eyes invalid / head valid cues was truly present and effective, it was this very discriminability that prevented any disparities between reaction time and accuracy across conditions to occur. If both the eyes and the head were to be highly discriminable, they would both be inclined to stand out in contrast to other features or attentional cues, and thus any division of attention between cues would only be heightened. It was also this sense of discriminability that likely led to the dividing of attention, which further contributed to any one orientation (eyes or head) having less of an impact on the directing of attention.

Limitations

While the present study was very thorough in that it examined 9 different combinations of eye and head cues, this level of detail made it somewhat difficult to parse through results and ensure that all relevant comparisons across conditions were being made. The intention of the experiment was to compare all conditions in a systematic manner, which for the most part was successful, though focusing on the differences between so many variables made it more challenging to hone in on the results of a smaller, more relevant pool of conditions. By categorizing head and eye combinations into so many distinct conditions, the potential for obtaining significant results was decreased, as hypotheses had to become more specific to accommodate for directionality and more complex interactions between conditions. The data was spread thinner across a large variety of conditions (rather than concentrated amongst a select few), and thus effect sizes were likely smaller than they could have been. However, to address the full scope of the interactions and competition between social cues that participate in our modeling of attention, it was arguably necessary to break down head and eye cues into so many different conditions.

Weaknesses could also be found within the experimental population, which was overwhelmingly white (84%) and had very little variance in terms of handedness (87% right-handed). However, when comparing the data of participants whose right hand was dominant with those who left hand was dominant, there were no notable differences between either reaction times or accuracies. There were also no differences in reaction times and accuracies between participants of different races/ethnicities, though it is possible that both of these results would not have replicated within a different population. Participants also occasionally reported mild eyestrain from staring at the blank white screen for 20 to 30 minutes, so there may have been improved reaction times, accuracies, and overall better focus on behalf of the participants if the background color of the experimental program was a slightly duller shade of white. There was also an interaction between the brightness of the screen and the amount of time participants chose to take breaks, as those who opted to take briefer breaks did not allow their eyes to recalibrate and rest before going back to staring at the bright screen, which may have further negatively impacted their performance. Breaks were also not imposed for set periods of time, as different individuals did not always feel ready to begin the experiment again after the same amount of time, and thus an element of consistency was lost.

Future Directions

In order to expand even further upon this experiment, it would be interesting to make alterations to the race and/or gender of the figure that serves as the cue. Out-group face recognition (being able to identify the faces of those belonging to a different demographic than oneself) has been proven to be poorer than in-group face recognition (being able to identify the faces of those belonging to the same demographic as oneself), and thus being of the same versus a different race and/or gender of the figure might impact the ways in which participants perceive and react (including the time in which they react) to them

(Hills et al., 2018). Hill speculated that this poor out-group face identification ability could be a result of less exposure to faces that look different from one's own, and suggested that also may be a product of being less motivated to process out-group faces as deeply as in-group faces. Regardless of the reason behind such poor out-group face recognition, the fact remains that not all participants within the current study would have described themselves as belonging to the same group as the individual in the figure (a white woman), and it is possible that their reaction times and accuracies would have been slightly different if this was not the case. While there were no notable differences in performance amongst students of different races/ethnicities within this particular experiment, it is possible that an effect would have be observed had the population been larger or more diverse.

Another alteration that could be made to this experiment in the future would be ensuring that the eyes and head of the figure are even more noticeably pointed in the opposite or same direction than they previously were, as such changes (however minor) could make reaction times more dependent on target validity. If the position of the eyes in relation to the head were to be more distinct, their relationship to the target would also become more obvious, making the act of identifying its orientation either faster or slower than before. This could either be achieved through a more thorough and professional portrait taking session, or alternatively, figures could be computer generated so as to maximize clarity within facial features and their respective orientations. For instance, if it is more obvious that the eyes are pointed to the side when the head is neutral or when it is pointing directly away from the eyes, in theory reaction times to valid targets should become even faster, and likewise, reaction times to invalid targets should become slower. It is possible that opting to heighten discriminability could also yield more significant results in regard to accuracy, as it would be expected that accuracy would increase if the head and eyes were indisputably in agreement, and decrease when they are without a doubt in opposition.

Lastly, the present study could be extended upon by introducing a neurodivergent population (in addition to the already present neurotypical population), as neurodevelopmental conditions such as autism spectrum disorder (ASD) are known to be associated with decreased social awareness, which also encompasses social attention (Lin et al., 2020). In a study conducted by Lin and colleagues, participants were divided into high autistic traits and low autistic traits groups using the Autism Quotient scale. Participants completed a spatial cueing task which involved the presentation of social cues (gaze) and non-social cues (an arrow) within conditions where the nature of the cue was predictable or unpredictable. The objective was to identify the location of the letter "T" that appeared on the screen, and individuals with high autistic traits benefited less (in terms of time taken to identify the T) from the unpredictable social cues as compared to low autistic trait individuals. However, these high autistic trait individuals benefited more than low autistic trait individuals when it came to unpredictable non-social cues. Thus, Lin and colleagues concluded that spatial attention impairment in high autistic individuals is not all encompassing, and is instead only present in the context of the social domain. In terms of the implications for the present study, it is possible that the eyes would not be as effective of a director of attention in neurodivergent populations than in neurotypical populations, and that in comparison the head may assume a more important role in the orienting of attention. If individuals find eye contact uncomfortable or simply uninformative, they may turn towards body language as the next best indicator of what someone is attending to, and subsequently extrapolate how they should respond in social settings. It is also quite possible that no social cues—the head included—would have an impact on reaction time, as unpredictable social cues (which the cues of the current experiment could be described as) have not previously been identified as being capable of improving reaction times within neurodivergent populations.

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