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Spatial Attention to Social Cues is not a Monolithic Process

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Abstract

Social stimuli are a highly salient source of information, and seem to possess unique qualities that set them apart from other well-known categories. One characteristic is their ability to elicit spatial orienting, whereby directional stimuli like eye-gaze and pointing gestures act as exogenous cues that trigger automatic shifts of attention that are difficult to inhibit. This effect has been extended to non-social stimuli, like arrows, leading to some uncertainty regarding whether spatial orienting is specialized for social cues. Using a standard spatial cueing paradigm, we found evidence that both a pointing hand and arrow are effective cues, but that the hand is encoded more quickly, leading to overall faster responses. We then extended the paradigm to include multiple cues in order to evaluate congruent vs. incongruent cues. Our results indicate that faster encoding of the social cue leads to downstream effects on the allocation of attention resulting in faster orienting.

Keywords: social cues; spatial cueing; selective attention; reflexive orienting; exogenous and endogenous attention

Introduction

At a crowded party surrounded by strangers, sharing a meal with friends, or catching the eye of your server on a café patio, we cannot help but notice and react to the actions of those around us. Through the language of glances and gestures, physical proximity, and facial expressions, we exchange invitations to interact. Interpreting and sending the right social cues is a fundamental part of communicating, building, and maintaining relationships. At the same time, we are not entirely beholden to the social world around us; in a crowded coffee shop, we manage to tune others out to finish our paper draft. The competition between noticing and engaging with others while completing our own personal goals is a fundamental question of what influences our attention and how these endogenous and exogenous processes interact.

Social cues, and in particular, gaze cues, are seen as fundamental to communication (Langton, Watt, & Bruce, 2000). For example, direct gaze can be seen as an invitation to interact, while averted gaze is often used to signal interest in other objects and may communicate an invitation for

others to jointly attend to the same thing. Adults and infants are highly sensitive to these gaze cues. Early in life, infants preferentially attend to faces and face-like stimuli (Farroni, Csibra, Simion & Johnson, 2002), while in adulthood, people can rapidly locate faces, even when embedded among numerous non-face distractors (Hershler, & Hochstein, 2005). Conversely, irrelevant faces interfere with locating other non-face objects in a search task (Langton, Law, Burton, & Schweinberger, 2008).

Beyond simply attracting attention, eyes, hands and faces can act as cues to distal locations or objects. Pointing, head turns, and gaze shifts have all been shown to shift attention toward the cued direction, aiding subsequent detection and identification of stimuli located there, with only a few hundred milliseconds' exposure to the cue (Driver, Davis, Ricciardelli, Kuhn, & Benson, 2007; Friesen, & Kingstone, 1998; Langton, & Bruce, 1999; Frischen, Bayliss, & Tipper, 2007; Crostella, Carducci, & Aglioti, 2009; Burton, Bindemann, Langton, Schweinberger, & Jenkins, 2009). In addition, this effect is resistant to interference, and these properties have led some to suggest that social cueing is automatic and stimulus driven. Indeed, this proposal is consistent with specialized processing of social cues in the brain, especially in the superior temporal sulcus (Allison, Puce, & McCarthy, 2000). Nevertheless, this view remains contentious since there is evidence from other neural activation studies showing a large degree of overlap between social and non-social stimuli (Tipper, Handy, Giesbrecht, & Kingstone, 2008), as well as behavioral evidence, including but not limited to spatial cueing tasks showing mixed results in distinguishing between social and non-social cues (Kuhn, & Benson, 2007; Eimer, 1997; Friesen, Ristic, & Kingstone, 2004; Tipples, 2002). Accordingly, exogenous cueing of attention may not be unique to social stimuli, but rather shared by the broader class of directionally-oriented stimuli.

If it is true that social stimuli are no different in their ability to orient attention, what other properties could explain the differences observed in other tasks? Birmingham and Kingstone (2009; Birmingham, Bischof, & Kingstone, 2008) suggest that the crucial difference lies in their

propensity for attracting, rather than their ability to orient attention. This argument, however, is incomplete, in that it fails to explain how the selection process distinguishes between social and non-social objects. One possibility is that encoding of the social stimuli occurs more quickly, allowing those items to compete for attentional resources sooner. In this light, the design of the standard spatial cueing paradigm (Posner, 1980) makes observing a difference less likely, as the presentation of a single, isolated cue at a known location obviates the need for selective attention. Furthermore, even if social cues are detected faster or with greater likelihood, the differences may be small and obscured by the additional time taken to orient towards the periphery, detect the target, and plan the appropriate motor response. Differentiating between the effects of these multiple component processes is necessary for identifying if and how social stimuli are different.

We began this investigation by using a standard spatial cueing paradigm to examine differences in the speed of detecting and responding to a peripheral target after the appearance of a non-predictive pointing hand or arrow cue. It has been argued that hands provide a more salient and accurate cue than eye gaze or head direction, but have received significantly less study (Langton et al., 2000; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). In line with previous research, we expected faster encoding and thus shorter reaction times in response to a pointing hand as compared to an arrow. Moreover, both types of stimuli have been shown to be effective cues, so we do not expect any difference in their cueing strength, measured as a validity effect (invalid – valid RTs).

Experiment 1

Methods

Participants were shown a non-predictive hand or arrow cue and tasked with responding to the location of a subsequently appearing peripheral target stimulus. The cue was visible for either 100 or 600ms before the appearance of the peripheral target. Prior research suggests that shorter delays tap into automatic or reflexive processes, while a greater delay permits more volitional or strategic responding (Friesen et al., 1998). Twenty-two undergraduate psychology students (11 female, between 18-24 years of age) participated as volunteers or for course credit. In all experiments, participants reported normal or corrected to normal vision and were naive to the purpose of the research.

Stimuli and Apparatus The stimuli were comprised of digital images of either a pointing hand or a flesh colored arrow created using Adobe AfterEffects CS5 (Adobe Systems, San Jose, CA), and were presented on a 36.6 x 27cm LCD screen operating at 1024 x 768 pixel resolution. Participants were seated approximately 70cm from the screen and responded using the ‘1’ or ‘3’ key on the computer number pad with their right middle- and index-

fingers. Stimuli were presented using E-Prime presentation software (Psychology Software Tools, Pittsburgh, PA).

Procedure Each trial began with a central, white fixation cursor, presented for 400, 500, or 600ms. The fixation disappeared and was replaced with the central cue, which remained visible throughout the rest of the trial. After a delay of either 100 or 600ms, the target appeared in the periphery and remained on screen until the participant made a response, or 5 seconds had elapsed. A blank screen was shown between trials for 600, 700, or 800ms (see Figure 1 for stimulus sizes and arrangement). Subjects were instructed to fixate on the center of the screen, and to respond to the location where the target appeared as quickly and accurately as possible. Additionally, they were informed that the cues were non-predictive, such that targets were equally likely to appear at the cued and uncued location

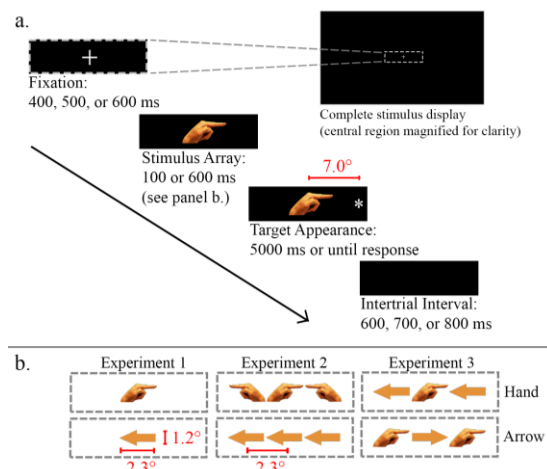


Figure 1. (a) Trial Procedure (b) Stimulus arrays used in Experiments 1-3. Sizes and distances visually exaggerated for clarity; true values shown in degrees of visual angle.

Design Three within-subjects factors were manipulated. Stimulus type referred to either a pointing hand or an arrow. The stimulus to target onset asynchrony (SOA) was 100 or 600ms. Validity referred to whether the target would appear at the location cued by the stimulus (valid) or to the opposite side of the screen (invalid).

These factors yielded 8 unique trial types, which were each presented with 20 repeats per block for 3 blocks, yielding 480 total trials per subject. Within each block, the direction of the central cue and the location of the target were counterbalanced for each condition. Before beginning the experiment, participants completed 16 practice trials and were provided feedback on their response time and accuracy. Feedback was not provided during the experimental trials.

The overall proportion correct was 98.4% across all participants. Due to the low amount of errors, we only analyzed correct responses. We also excluded trials with reaction times less than 100ms or greater than 800ms to

exclude anticipations and inattentive responses, which accounted for an additional 1.2% of the total trials. A 2x2x2 repeated-measures ANOVA with stimulus type, SOA, and validity as within-subjects factors was conducted.

Results & Discussion

Consistent with the results from previous studies, mean response times to valid trials (387ms) were faster than invalid trials (401ms), $F(1, 21) = 20.18, p < 0.001, \eta^2 = 0.490$. This result confirms that even though participants knew that the cues were irrelevant, they could not completely ignore them.

Response times were also affected by the SOAs. The 600ms SOA produced faster overall responses (375ms) than the 100ms delay (413ms), $F(1, 21) = 191.95, p < 0.001, \eta^2 = 0.901$. This is likely due to participants having additional time to prepare a response (Driver, et al. 1999).

We hypothesized that the social nature of the pointing hand would lead to faster encoding, and thus shorter reaction times than the arrow. Our results were consistent with this prediction in that the mean reaction time was faster to the hand than to the arrow (392 and 397ms respectively), $F(1, 21) = 10.18, p < 0.01, \eta^2 = 0.327$, though the difference was small. The interaction between stimulus and SOA was not significant, $F(1,21) = 3.70, p = 0.068$, suggesting that the additional response preparation benefitted both stimulus types similarly. Plots showing the main effects are shown in Figure 2.

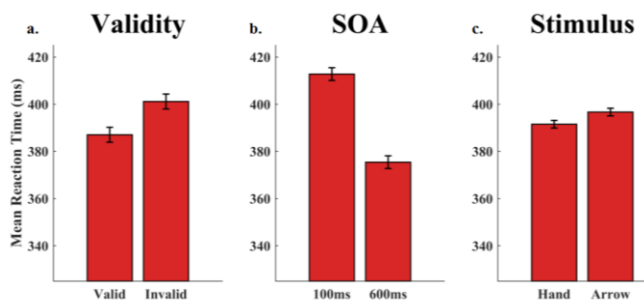


Figure 2. Reaction time means and standard error shown for responses in Experiment 1. Main effects of (a) Validity (b) SOA and (c) Stimulus.

We also tested whether there was a difference between valid and invalid cues. The size of the validity effect was calculated as the mean invalid – valid RT. Response times were analyzed in a 2x2 repeated-measures ANOVA with stimulus and SOA as within-subjects factors. Critically, the stimulus type was not significant, $F(1, 21) = 0.75, p = 0.396$, nor was SOA, $F(1, 21) = 0.05, p = 0.826$, or the interaction, $F(1, 21) = 0.15, p = 0.706$. These results are consistent with our hypothesis that both cues are equally effective at shifting attention toward the target for both automatic (100ms SOA) as well as more intentional (600ms SOA) responses.

The overall pattern of results was consistent with faster encoding of the pointing hand, but the cueing strength for

both hand and arrow stimuli (i.e., no stimulus effect for the validity measure) showed no difference. We earlier proposed that this encoding difference is critical in explaining how attention can be selectively oriented towards social stimuli. In order to test this hypothesis, we needed to increase the difficulty of the task to include multiple cues.

Experiment 2

White, Ratcliff, and Starns (2011) studied the effect of surrounding a central cue with flankers on directional judgments, and suggest that multiple cues can simultaneously contribute to a directional decision. In this experiment, we utilized a similar paradigm to explore whether the addition of flanking stimuli facilitate or interfere with processing of the central cue.

Methods

Twenty undergraduate psychology students (14 female, between 18-22 years of age) participated in this experiment as volunteers or for course credit. Participants reported normal or corrected to normal vision and were naive to the purpose of this research.

Stimuli and Apparatus We modified the stimuli from Experiment 1 by pairing the central cue with two additional cues of the same type, i.e. three hands arranged horizontally. The two flankers were always oriented in the same direction as each other, but could point in the opposite direction of the central cue. The total horizontal extent of the stimuli subtended 6.9° visual angle. The distance between the target and the central cue remained the same as Experiment 1.

Design

As in Experiment 1, we manipulated the stimulus type (hand vs. arrow), and the SOA between cue and target (100 vs. 600). With the addition of the two flanking cues, validity was defined as the relationship between the *central* cue and the target location. We term the relationship between the directionality of the flankers and the central stimulus ‘congruence.’ Trials were ‘congruent’ when all three stimuli pointed in the same direction, and ‘incongruent’ when the central cue pointed opposite the two flankers. Thus, on a ‘valid, congruent’ trial, all three stimuli pointed toward the target, while on an ‘invalid, congruent’ trial, none of them did. Conversely, on a ‘valid, incongruent’ trial, the central cue alone pointed towards the target location, while on an ‘invalid, incongruent’ trial, only the flankers pointed toward the target. Again, we emphasize that none of the cues were predictive of the target location, and subjects were informed about this property.

The full-factorial design yielded 16 conditions, each of which was presented 10 times per block, which was repeated three times for a total of 480 trials. Before beginning the experiment, participants completed 16 practice trials and were provided feedback on their response time and accuracy. We excluded incorrect trials (2.4%) and filtered based on RT (additional 0.6%) of trials.

Results & Discussion

In accordance with Experiment 1, subjects responded faster when the SOA was 600ms (355.8ms) than 100ms (396.5ms), $F(1, 19) = 124.39, p < 0.001, \eta^2 = 0.867$. Additionally, the central cue seemed to exhibit a stronger overall effect than the flankers, as the main effect of validity was also significant, $F(1, 19) = 6.52, p = 0.019, \eta^2 = 0.255$, with faster overall RTs for valid trials (374.1ms) than for invalid (378.5ms). In contrast to Experiment 1, there was no main effect of stimulus on response times, $F(1, 19) = 1.69, p = 0.209$, with reaction times to the hand (375.3ms) nearly identical to those for the arrow (377.4ms). One explanation is that the redundant cueing of the flankers facilitated encoding for both stimulus types, bringing both close to a floor, or minimum, encoding time.

We expected the flankers to contribute some influence on orienting beyond the central cue. The interaction of congruence and validity was significant, $F(1, 19) = 64.67, p < 0.001, \eta^2 = 0.773$, indicating that the arrangement of the flankers influenced response times (see Figure 3).

To better understand the role of the flankers on orienting, we tested the validity effect. On congruent trials we observed a mean RT advantage for valid trials of 23ms, while incongruent trials showed an advantage in the opposite direction, on average of 14ms, a reversal of 34ms. These differences were both significantly different from zero, $t(19) = 7.47, p < 0.001, t(19) = -4.80, p < 0.001$ for congruent and incongruent trials respectively. The incongruent flankers thus not only mitigated the cueing effect of the central stimulus, but actually exerted a greater influence and shifted attention to the opposite side. This is a critical finding because it indicates that, while located away from participants' point of gaze, the two flanking stimuli were attended and exerted a greater net influence on orienting than the central cue. Lastly, the interaction of congruence with stimulus type was not significant, $F(1, 19) = 1.84, p = 0.191$, suggesting the strength of the cues was the same for both types of stimulus.

The greater cueing strength provided by the redundant cues appears to have created a floor effect and eliminated the stimulus specific effects seen in Experiment 1. To test our critical hypothesis, that encoding speed differences will predict differential allocation of attention towards social vs. non-social stimuli when the two are present simultaneously, we modified the current paradigm by placing hands and arrows together in the same stimulus array.

Experiment 3

In the preceding experiment, flankers modulated the directional influence of the central cue when all three stimuli were from the same class. In this experiment, we test the critical prediction of the selection hypothesis: when presented with both social and non-social stimuli, attention should be biased towards processing the social cues as the result of faster encoding. Specifically, we predict that incongruent flanking arrows will not significantly interfere with a central hand, and thus a validity effect (valid <

invalid) will still be observed. By contrast, incongruent flanking hands should interfere with the central arrow resulting in a reverse of the validity effect (invalid < valid).

Methods

The procedure and design for Experiment 3 was identical to Experiment 2 with one exception; rather than showing three of the same stimuli, we included hands and arrows within the same display. The flankers were always pairs of the same class (e.g. two arrows or two hands) and matched with a central cue from the other class (e.g. hands flanking a single arrow or vice versa). Overall error percentages were low (0.5% of trials) and filtering based on reaction times excluded another 1.1% of trials.

Results & Discussion

In line with the previous experiments, we observed a main effect of SOA, $F(1, 19) = 296.79, p < 0.001, \eta^2 = 0.940$ with longer SOAs showing faster responses, and a main effect of validity, $F(1, 19) = 30.67, p < 0.001, \eta^2 = 0.617$, with valid responses overall faster than invalid.

Our main prediction was that the flankers would produce different effects depending on the stimulus arrangement. When the arrows flanked the hand, we expected them to have a smaller effect than when the hands flanked the arrows. For congruent stimuli, the addition of the flankers should bolster the validity effect. This was the case: the addition of congruent hand flankers provided a bigger boost to the central arrow (21ms) than the congruent arrows provided the central hand (14ms). When all three stimuli were hands the validity effect was larger (Experiment 2; 22.3ms) than when the flankers were arrows (Experiment 3; 14ms), though a post-hoc t-test showed no significant difference, $t(38) = 1.85, p = 0.073$ (two-tailed).

Even more striking are the results from the incongruent condition. When the hands and arrows provided conflicting information, targets in the direction cued by the hand(s) always led to faster response times, regardless of whether they were placed in the center or appeared as flankers. This effect is visible as a 10ms reversal of the validity effect between centrally presented hands and arrows (see the blue bars in Figure 4). Consistent with these results, the interaction between stimulus and congruence was significant, $F(1, 19) = 5.24, p < 0.05, \eta^2 = 0.216$.

Together, these results suggest that the pointing hand stimuli automatically drew attention at the expense of attention towards the arrows. The asymmetry of the flankers' influence is best understood in terms of faster encoding of the hands as compared to the arrows. This initial difference during encoding resulted in a cascading effect, leading to faster responses to targets cued by the direction of the hands.

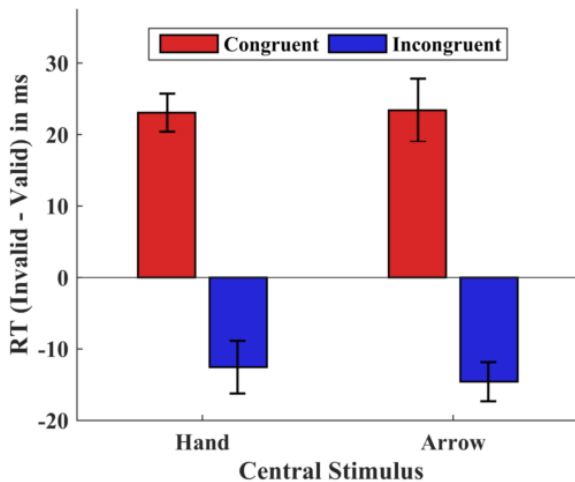


Figure 3. Validity effect (Invalid – Valid reaction times) for response times in Experiment 2. Here we show the main effect of Stimulus and lack of interaction of the Stimulus type with Congruence.

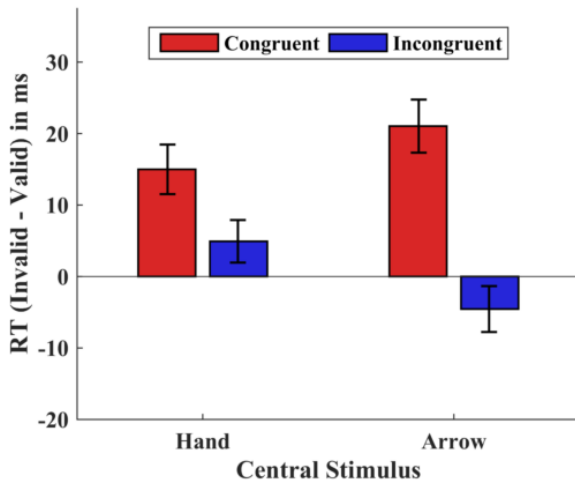


Figure 4. Validity effect for response times in Experiment 3, showing the interaction between Stimulus and Congruence. Note the label on the x-axis refers to the central stimulus which was always paired with flankers from the other class.

One alternative explanation for the differences in Experiment 3 is that the stimuli differed on low-level features like contrast or spatial frequency. In order to address this question, we utilized a computational salience algorithm (Harel, Koch, & Perona, 2006) to compute a feature-based prediction of attention for each stimulus array. To rule out a featural bias towards the flankers, we calculated the ratio of the total salience on the flankers relative to the central cue. These ratios did not correlate with the size of the validity effect, $p = 0.982$, suggesting any low-level changes were insufficient to account for the changes we saw. Flanker to central ratios and graphical depictions of

the predicted distributions for each stimulus configuration are shown in Figure 5.

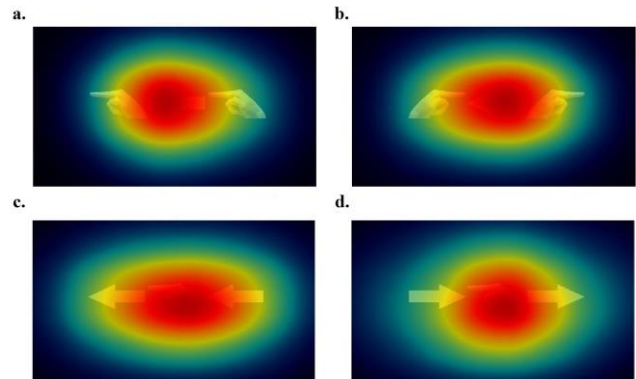


Figure 5. Output from the salience algorithm (Harel et al., 2006) showing the feature-based prediction of the distribution of attention and flanker-to-central ratios for the four stimulus configurations used in Experiment 3. (a) Congruent, Arrow: 1.33 (b) Incongruent, Arrow: 1.42 (c) Congruent, Hand: 1.57 (d) Incongruent, Hand: 1.37.

General Discussion

In Experiment 1, we showed that the pointing hands generated faster overall response times, but saw no difference in the magnitude of the validity effect. These results are in line with faster encoding of the social cue, but no difference in speed of orienting. We modified the basic paradigm in Experiment 2 to include flankers from the same stimulus type as the central cue. The presence of the flankers modulated the effect of the central cue on both congruent and incongruent trials, suggesting simultaneous processing of all three stimuli. Moreover, their presence eliminated the stimulus differences in Experiment 1, which suggests that the redundant cues facilitated encoding of both the hands and arrows. Finally, in Experiment 3, we leveraged participants' ability to process multiple cues to pit pointing hands and arrows against one another. We found evidence suggesting that participants' faster encoding of the hand stimuli resulted in preferential attention towards the hands, and ultimately a greater influence on subsequent orienting.

Previous research has brought to light important differences in the way we attend and process social stimuli, but has struggled to disentangle the multitude of component processes that contribute to the observed results. Our findings are consistent with the position put forth by Birmingham and Kingstone (2009) which proposes that social stimuli preferentially attract attention. Moreover, we suggest this preference emerges as a downstream effect of early encoding differences.

The competing explanation, that the differences between social and non-social stimuli lie in the speed of orienting, was not supported. The validity effect provides a measure of the strength of the stimulus cue for covertly orienting attention. The size of the validity effect was no different

between the hands and arrows in either Experiment 1 or Experiment 2. Only in Experiment 3, when the two stimuli competed for attention, did we see a stronger validity effect in favor of the hands on both congruent and incongruent trials. These results are most parsimoniously explained by faster encoding of the directionality of the pointing hands, without positing the additional effect of orienting differences.

An alternative account of the observed difference between the hand and arrow is via low level features like spatial contrast. We employed one algorithm and found no relationship between the computed salience of the stimuli and participants' relative attention towards the central and flanking cues. However, a number of limitations preclude us from completely ruling out this account. This algorithm was designed to estimate where subjects would fixate during an extended, free viewing paradigm, and our stimuli occupied a relatively small region of the screen subtending only about 7° of visual angle. Subjects were instructed to attend to the preceding fixation cursor and knew the location of the stimulus array, so it is reasonable to assume their point of gaze was directed towards the stimuli. This approach thus only provides an account of how attention may have been distributed across the multiple stimuli during the first fixation. To better distinguish between category and feature-based accounts, future experiments should directly manipulate low level properties as in the work of Sui, Rotshtein, and Humphreys (2013).

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