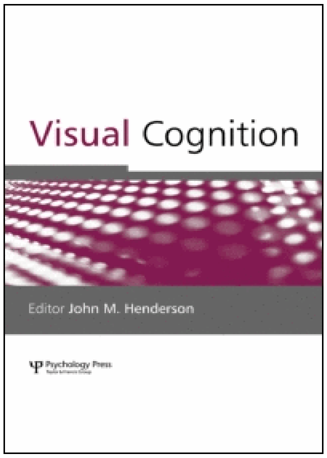

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Gaze selection in complex social scenes

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Gaze selection in complex social scenes

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A great deal of recent research has sought to understand the factors and neural systems that mediate the orienting of spatial attention to a gazed-at location. What have rarely been examined, however, are the factors that are critical to the initial selection of gaze information from complex visual scenes. For instance, is gaze prioritized relative to other possible body parts and objects within a scene? The present study springboards from the seminal work of Yarbus (1965/1967), who had originally examined participants' scan paths while they viewed visual scenes containing one or more people. His work suggested to us that the selection of gaze information may depend on the task that is assigned to participants, the social content of the scene, and/or the activity level depicted within the scene. Our results show clearly that all of these factors can significantly modulate the selection of gaze information. Specifically, the selection of gaze was enhanced when the task was to describe the social attention within a scene, and when the social content and activity level in a scene were high. Nevertheless, it is also the case that participants always selected gaze information more than any other stimulus. Our study has broad implications for future investigations of social attention as well as resolving a number of longstanding issues that had undermined the classic original work of Yarbus.

Imagine the following scenario. You are walking down a busy city street and you notice that a woman has stopped walking and is gazing upward. Using her gaze direction, you turn your eyes to see what she is looking at.

As this simple example illustrates, folk knowledge suggests that we are very interested in the attention of other people, and that we use their eyes to

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infer where, and what they are looking at. Moreover, we seem to do this in at least two distinct stages. First, we *select* the eyes as a key social stimulus, and second, we *shift* our attention from the eyes of someone to the location/object that someone is looking at.

To date, research has focused on the second stage of this equation by examining the extent to which gaze direction can trigger an attention shift in others and seeking to uncover the neural circuitry that subserves this attention shift. As a result, it is now firmly established that infants (Hood, Willen, & Driver, 1998), preschool children (Ristic, Friesen, & Kingstone, 2002), and adults alike (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999) shift attention automatically to where others are looking. Single cell (Perrett et al., 1985), brain lesion (Campbell, Heywood, Cowey, Regard, & Landis, 1990), and functional neuroimaging studies (Bentin & Golland, 2002; Dolan et al., 1997; Kingstone, Tipper, Ristic, & Ngan, 2004) have implicated specific brain areas, such as the superior temporal sulcus and the superior parietal lobe, as critical neural components of this orienting process.

While this extant body of research has made a number of major inroads into the *shift* of attention that is triggered by a gaze cue, it has left relatively untouched the question of what factors are critical to the initial *selection* of gaze information prior to an attentional shift to a gazed-at location. Indeed, in a typical study the social cue—that is, the eyes—is *preselected* by the experimenter so that it, along with its associated facial features (e.g., head, nose, mouth), are the only stimuli that a participant receives. As a result, in a typical study, participants are presented just with a face (often a schematic face) with no other body parts or objects shown to the subjects. Clearly, this approach of preselecting and isolating the social cue circumvents the critical issue as to what factors are important to the selection of gaze information when it is embedded in complex real-world situations.[1]

This point would perhaps be moot if it were firmly established that gaze is normally selected in complex visual scenes. However, this matter is far from confirmed, both because it has rarely been examined empirically and because, on the rare occasions it has been tested, the data do not provide

[1] It is worth noting that the routine preselection of gaze information may also have led researchers to overestimate the influence of gaze direction on the orienting of attention, at least within standard research paradigms. For instance, it has recently transpired that other directional cues, such as arrows (Ristic et al., 2002; Tipples, 2002) and the words "left" or "right" (Hommel, Pratt, Colzato, & Godijn, 2001), can produce rapid, reflexive shifts of attention that closely approximate (if not duplicate) the attention shift triggered by gaze. This raises the real possibility that many of the orienting effects to gaze direction that were initially attributed to gaze being a "special social cue" (e.g., Driver et al., 1999; Friesen & Kingstone, 1998) may have grossly overstated their case (see Gibson & Kingstone, 2006; Ristic, Wright, & Kingstone, 2006, for further considerations of this matter).

any clear support for the idea that eyes are prioritized within complex scenes. The seminal work of Yarbus (1965/1967) provides an ideal demonstration of these points.

Continuing the earlier work of Buswell (1935), Yarbus is one of the few investigators to have examined how people scan scenes containing complex social information. To be sure, Yarbus is well-known for showing that people will look preferentially at the eyes of a face that is displayed in isolation (see, for example, Panel A in Figure 1). But what has routinely been overlooked is that Yarbus also studied how people examine images that contain a face along with its associated body parts. An examination of these data, an example of which is illustrated in Panel B of Figure 1, reveals that there is no obvious preferential scanning of the eyes relative to other parts of the body. These data raise the possibility that the selection of gaze information may not have priority within many complex real-world situations.

Interestingly, in another well-known study, Yarbus showed participants a picture of the Repin painting *An Unexpected Visitor* and found that there was a tendency to look at the heads and faces of the people in the scene (see Panel C of Figure 1). Note that this finding conflicts with the Yarbus data above showing that the eyes are not prioritized when a lone individual is viewed along with their associated body parts. This discrepancy suggested to us two possible explanations. One is that increasing the social content of a scene, by adding more people to it, may increase the tendency for observers to look at the eyes of other people. An alternative explanation is that it is not the social content of the scene per se that is critical, but the level of activity within it, that enhances fixations to the eyes. For instance, in Repin's painting the characters were doing something (e.g., walking, opening the door), and the eyes may have contained information that was important for interpreting these activities.

A concern for both of these proposals, however, is that the participants in Yarbus' study were familiar with Repin's painting and its meaning, and that their scanning of this picture may have reflected a shared understanding of the painting. In other words, the "task set" that participants brought to the situation may have impacted the scanning of the scene itself. Importantly, Yarbus himself raised precisely this caution regarding his study of Repin's painting, and reinforced this consideration by demonstrating that he could change people's scanning patterns simply by asking them different questions regarding the picture. For instance, if he asked observers to remember the clothes worn by the people in the painting, then the observers no longer focused on the heads and eyes but on the clothes being worn by the people in the painting. There are also, unfortunately, a number of other shortcomings related to the Repin study. Besides testing only a small number of participants with a picture that they were intimately familiar with, it was the *only* complex social scene Yarbus presented to the participants. Thus,

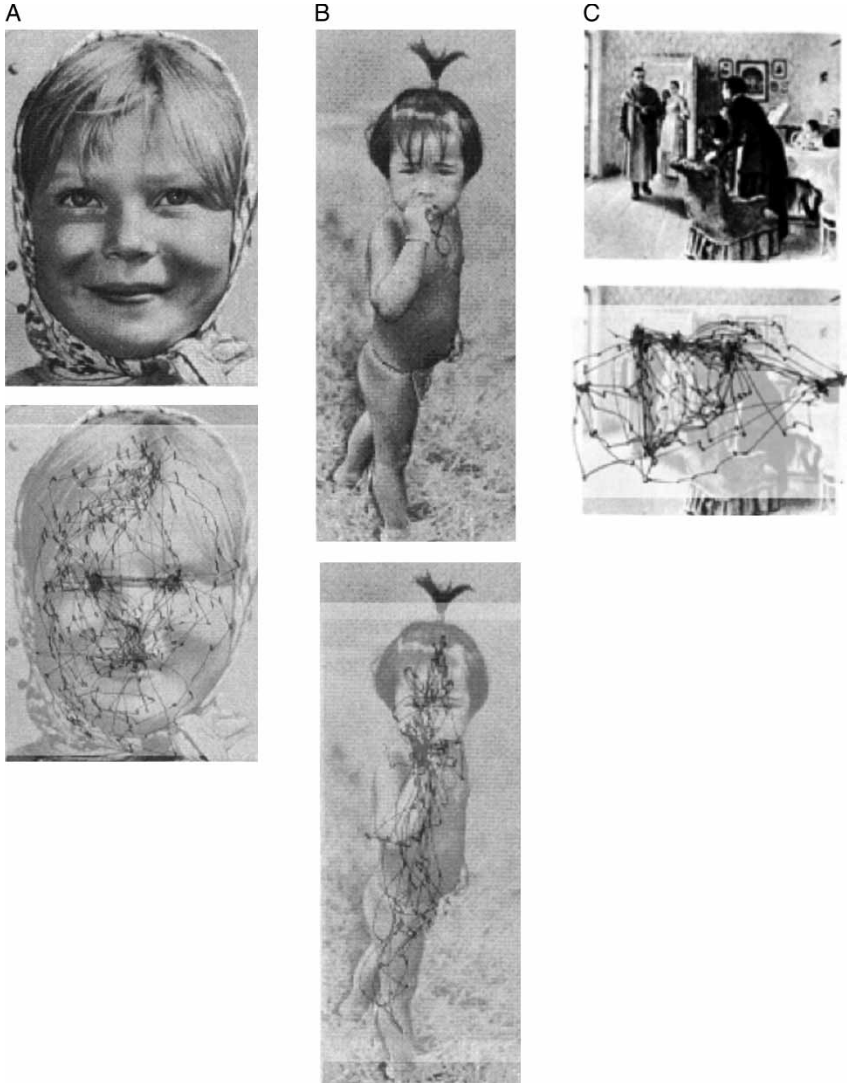

Figure 1. Scan paths produced in Yarbus' (1965/1967) study, in which participants freely viewed a set of images. A: Scan paths for an individual face, showing a selective preference for the eyes. B: Scan paths for a face accompanied by the rest of the body. Note that the preference for eyes is greatly reduced compared to when viewing an individual face. C: Scan paths for a social scene, Repin's *An Unexpected Visitor.* Here a preference for faces/eyes is again observed. Adapted from Yarbus (1965/1967) *Eye Movements and Vision*, reproduced with kind permission of Springer Science and Business Media.

one does not know whether Yarbus' findings are particular to the situation depicted in Repin's painting, or whether they generalize to other social scenes. Finally, and perhaps most troublesome of all, the resolution of Yarbus' eye monitor does not permit one to disentangle selection of gaze information from selection of other facial features. Thus, the study by Yarbus is suggestive that people may prefer to look at the eyes of others when several people are depicted in a scene, or, alternatively, when there is activity in the scene, but his study is far from conclusive on this issue.

The aim of the present study was to answer four main questions regarding the selection of gaze information. First, do people prioritize the eyes of people when gaze information is embedded in a number of different complex visual scenes? Second, is the selection of gaze information affected by the task given to observers? Third, does variation in social content of a scene impact the selection of gaze information? Fourth, does variation in the activity level within a scene influence gaze selection?

To get at these questions, we presented participants with 20 complex real-world scenes that contained either one person or three persons. The actors in these scenes were either doing something (e.g., reading a book; *active scenes*) or were doing nothing (e.g., just sitting on their own; *inactive* scenes). Participants were given one of three possible tasks. For one group, participants were asked to simply look at the scenes that they were shown (Look task). As the participants knew that they were being eye monitored (and thus they knew that where they were looking was of interest to the study), we considered this to be the most neutral possible task instruction. Therefore the Look task provided a baseline against which to compare the other task instructions. Participants in a second group were asked to describe the scene (Describe task). Note that, like the Look task, this instruction does not emphasize any particular aspect of the scenes. Participants in a third group were asked to describe where people in the scene were directing their attention (Social Attention task). Thus, the task was again to describe the scene but now the instruction reflected the folk understanding that people look to the eyes in a scene to understand where social attention is being committed (see also Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006).

METHOD

Participants

Thirty-nine undergraduate students from the University of British Columbia participated. All had normal or corrected-to-normal vision, and were naïve to the purpose of the experiment. Each participant received course credit for participation in a 1-hour session.

Apparatus

Eye movements were monitored using an Eyelink II eye tracking system. The online saccade detector of the eyetracker was set to detect saccades with an amplitude of at least 0.5°, using an acceleration threshold of $9500°/s^2$ and a velocity threshold of 30°/s.

Stimuli

Full colour digital photos were taken of different rooms in the UBC Psychology building. Image size was 36.5×27.5 (cm) corresponding to $40.1° \times 30.8°$ at the viewing distance of 50 cm, and image resolution was 800×600 pixels. Each of the 20 scenes used contained either one person or three persons, either doing something (e.g., sitting and playing cards; *active scenes*) or doing nothing (e.g., just sitting on their own; *inactive scenes*). Examples of these scene types are presented in Panel A of Figure 2. Due to differences in the number of people (one or three) and variation in distance between the people and the camera, the eye region varied in area from 1.69 deg^2 to 9.45 deg^2, with an average area of 4.92 deg^2. Specific experimental details are presented below.

Procedure

Participants were seated in a brightly lit room, and were placed in a chinrest so that they sat approximately 50 cm from the display computer screen. Participants were told that they would be shown several images, each one appearing for 15 s. Each participant was randomly assigned to one of three tasks. The Look group was told to simply "look at" each image. The Describe group was told to "look at, and then describe" each image. The Social Attention group was asked to "describe where attention is being directed in the scene". The describe and social attention groups were given an answer booklet, with space available for answering their assigned question for each picture in the order presented. Participants were told that they would have to write their answer for any given picture *after* the trial was over, i.e., after the image disappeared, and that they could take as long as they needed to write their answer.

Before the experiment, a calibration procedure was conducted. Participants were instructed to fixate a central black dot, and to follow this dot as it

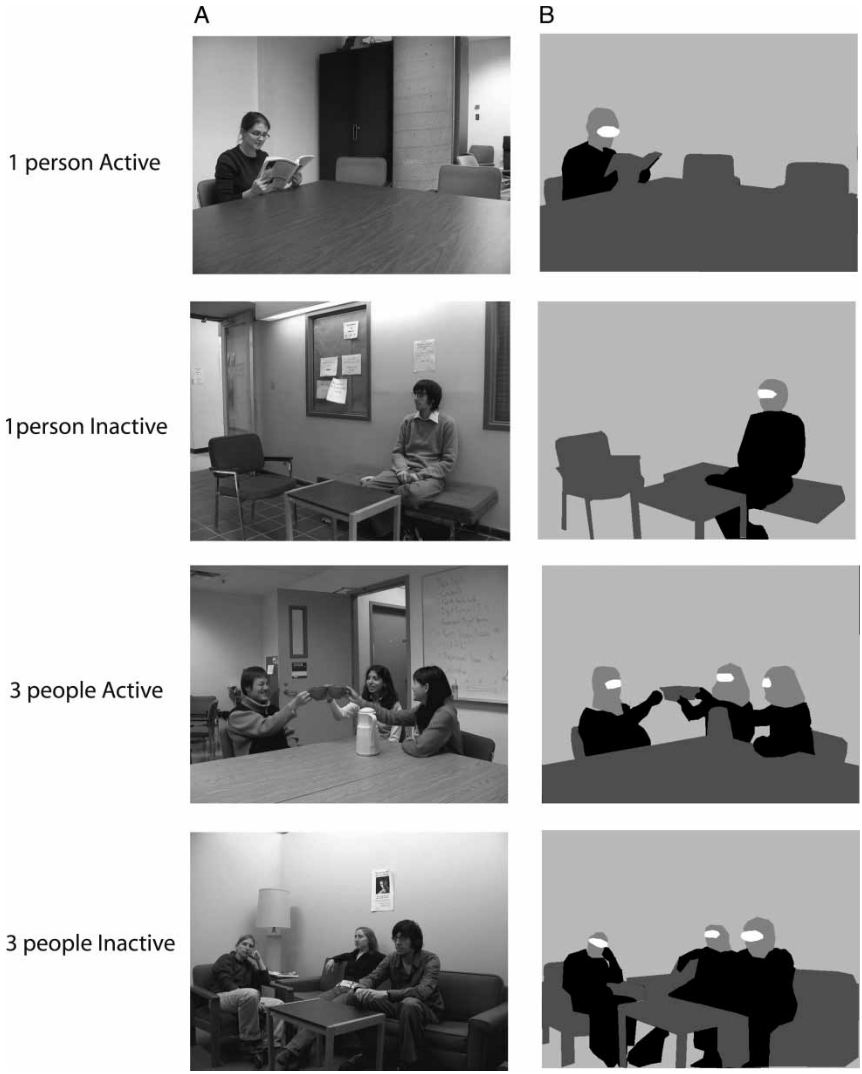

Figure 2. A: Examples of the four scene types. From top to bottom: 1-person active, 1-person inactive, 3-people active, 3-people inactive. In active scenes, the actors were involved in some kind of action (e.g., reading, playing cards, conversing). In inactive scenes, the actors were sitting quietly on their own. B: Corresponding regions of interest used in analysis (eyes, head, body, foreground objects, background).

appeared randomly at nine different places on the screen. This calibration was then validated with a procedure that calculates the difference between the calibrated gaze position and target position and corrects for this error in future gaze position computations. After successful calibration and validation, the scene trials began.

At the beginning of each trial, a fixation point was displayed in the centre of the computer screen in order to correct for drift in gaze position. Participants were instructed to fixate this point and then press the spacebar to start a trial. One of 20 pictures was then shown in the centre of the screen. Each picture was chosen at random and without replacement. The picture remained visible until 15 s had passed, after which the picture was replaced with the drift correction screen. During this time, participants in the describe and social attention groups wrote an answer using the booklet provided. This process repeated until all pictures had been viewed.

RESULTS

For each image, an outline was drawn around each region of interest (e.g., "eyes") and each region's pixel coordinates and area were recorded. We defined the following regions in this manner: eyes, heads (excluding eyes), bodies (including arms, torso, and legs), foreground objects (e.g., tables, chairs, objects on the table), and background objects (e.g., walls, shelves, items on the walls). Panel B of Figure 2 illustrates these regions. Regions were pooled, such that there was one composite "eye" region made up of all eye regions, one composite "head" region made up of all head regions, etc.

To determine what regions were of most interest to observers we computed *fixation proportions* by dividing the number of fixations for a region by the total number of fixations over the whole display. These data were area-normalized by dividing the proportion score for each region by its area (Birmingham, Bischof, & Kingstone, in press; Smilek et al., 2006). Note that in doing so we also corrected for changes in the area covered by eyes across scenes with different numbers of people.

To determine where observers' initial saccades landed in the visual scene, we computed the number of first fixations and second fixations that landed in a region (*initial fixations*). First fixations were randomly distributed, consistent with the full-field stimulation that occurred with the abrupt onset of a scene, so our initial fixation analyses focus on the second fixation data. We also computed the time it took observers to fixate a region for the very first time. To ensure that outliers did not skew the mean effects, we excluded first-fixation latencies that followed display onset by less than 100 ms or more than 2 s.

We submitted the fixation proportion data to a $3 \times 2 \times 2 \times 5$ mixed analysis of variance (ANOVA) with task (look, describe, social attention) as the between-subjects factor and people (1 person vs. 3 people), activity

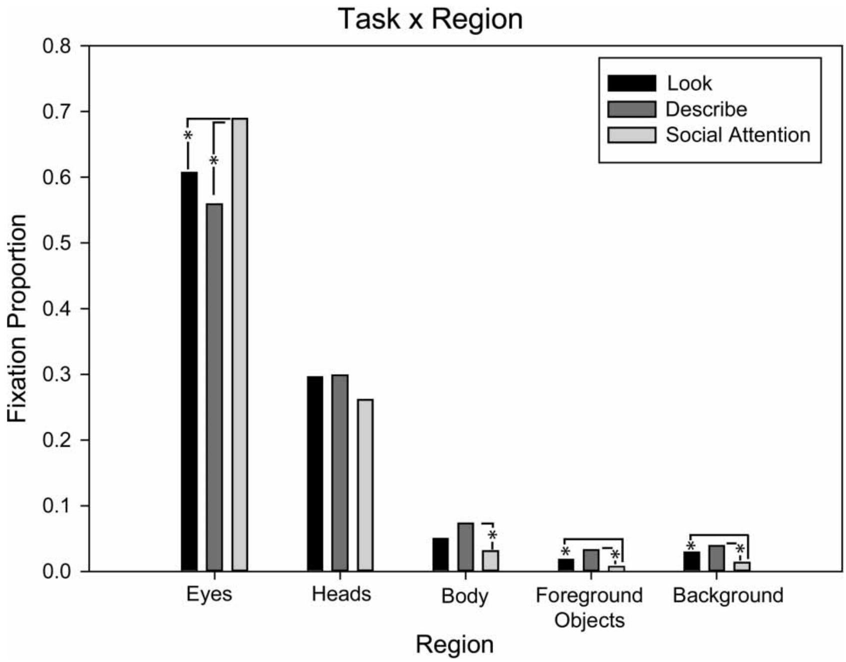

Figure 3. Fixation proportion data plotted as a function of task and region. Observers fixated the eyes the most, followed by heads, bodies, background, and foreground objects. The social attention group showed enhanced fixations to the eyes, but decreased fixations to the bodies, foreground objects, and background regions relative to the baseline tasks. *indicates a significant difference in means using pairwise comparisons ($p < .05$).

(inactive vs. active), and region (eyes, head, body, foreground, background) as within-subjects factors.

Question 1: Is gaze information preferentially selected from complex scenes?

Figure 3 shows these data for each region as a function of task. Looking at this figure it is evident that for each group eyes were fixated far more often than any other region, as reflected by a main effect of region, $F(4, 144) = 542.10$, $p < .001$. Pairwise comparisons, Fishers LSD $p < .05$, revealed that the eyes were fixated the most ($M = 0.62$), followed by heads ($M = 0.28$), bodies ($M = 0.05$), background ($M = 0.03$), and finally other objects ($M = 0.02$). The initial fixation data (Figure 4) showed that this preference for eyes emerged early on, with fixations being more likely to land on the eyes or heads than any other region, reflected by a main effect of region, $F(4, 144) = 34.65$, $p < .0001$; Fishers LSD pairwise comparisons,

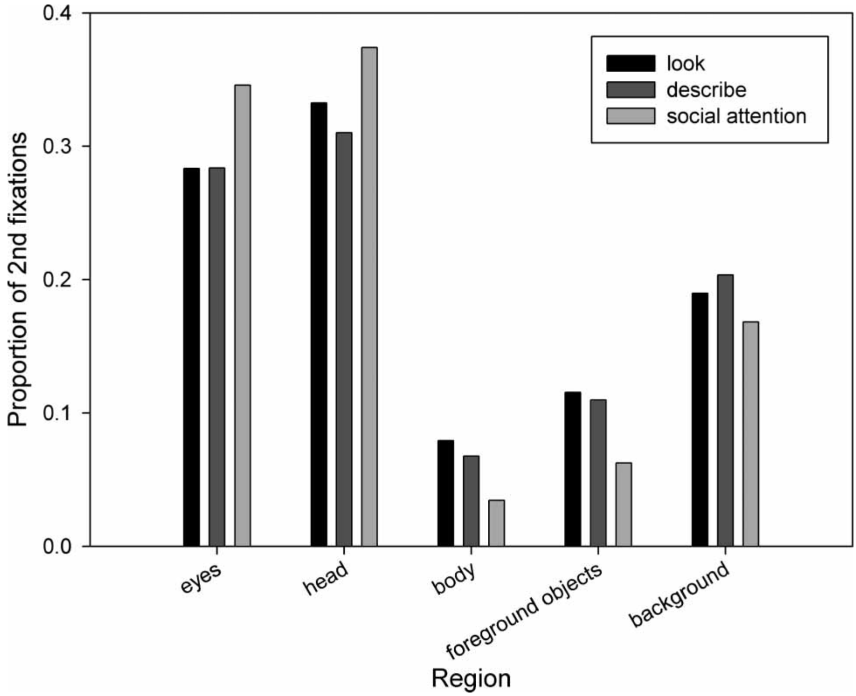

Figure 4. Proportion of second fixations falling on eyes, heads, bodies, foreground objects, or background, as a function of task (look, describe, social attention). The eyes and heads were more likely than any other region to receive a second fixation.

$p < .05$. This finding dovetails with the latency to first fixate a region, with observers fixating eyes and heads equivalently ($M = 499$ ms) and significantly sooner than any other region ($M = 923$ ms), reflected by a main effect of region, $F(4, 142) = 18.46$, $p < .0001$; Fishers LSD pairwise comparisons, $p < .05$.

Question 2: Does the task of describing social attention drive fixations to the eyes?

It is also clear from Figure 3 that eyes were fixated more often in the social attention task than the look or describe tasks, resulting in a Task × Region interaction, $F(8, 144) = 3.73$, $p < .0001$. Interestingly, while there were greater fixations to the eyes for the social attention task (Fishers LSD, $p < .05$), than the describe or look tasks (which did not differ from each other, $p > .05$), fixations to the head regions were similar in all three tasks, whereas there were significantly fewer fixations to the other regions (e.g., body, foreground objects, background) for the social attention task relative to the other tasks (Fishers LSD, $p < .05$). The initial fixation data (Figure 4) showed that the interest in eyes and heads did not differ as a function of task early on ($F < 1$). Thus, the increased preference for eyes in the social attention task appeared to be strategic in nature, emerging after an initial interest in eyes that was equal across tasks.

Questions 3 and 4: Does social content or activity affect gaze selection?

Recall that based on Yarbus' Repin study we had hypothesized that increasing the social content of a scene or increasing the activity within a scene, might drive people to look more at the eyes. Figure 5 presents the data that addresses this issue. Here we see that, indeed, increasing the social content of a scene, by adding more people to it, increases fixations to the eyes, but only when there is activity occurring within a scene. This is reflected by a significant People × Activity × Region interaction, $F(4, 144) = 3.17$, $p < .05$, and confirmed by a one-tailed pairwise comparison, $p < .05$. When there

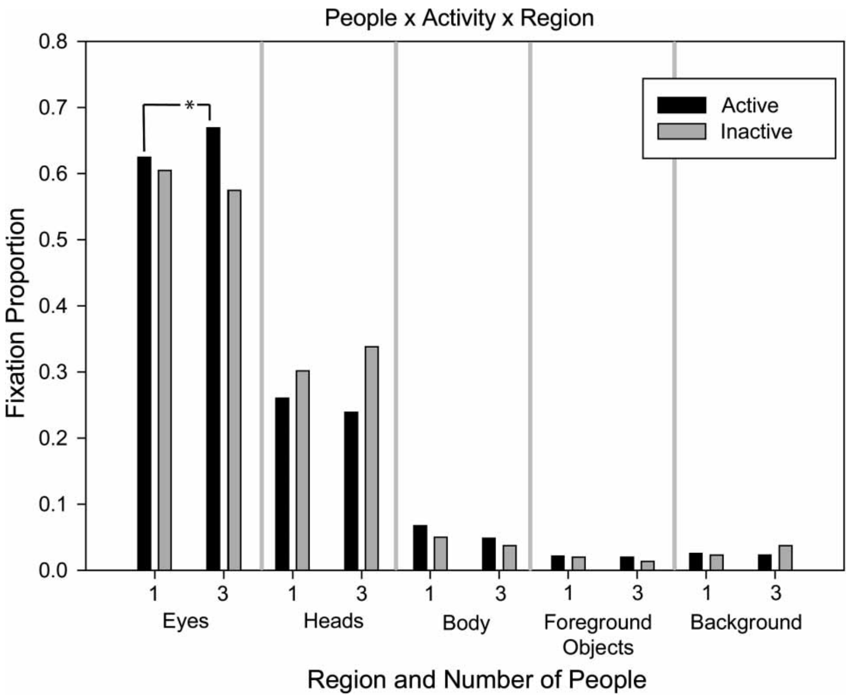

Figure 5. Fixation proportion data for plotted as a function of people, activity, and region. Fixations to eyes were enhanced by increasing social content (i.e., 3-people scenes vs. 1-person scenes) when the scenes contained activity (active scenes). *indicates a significant difference in means using pairwise comparisons ($p < .05$).

is no activity in the scene, there is no effect of adding people, $p > .05$. Note that these findings did not vary as a function of group and that there were no higher order interactions in our analyses.

GENERAL DISCUSSION

The present study set out to answer four main questions. First, do people prioritize the eyes of people when gaze information is embedded in a number of different complex visual scenes? Second, does the task of describing attentional states in the scene enhance fixations to the eyes? Third, does variation in social content of a scene impact the selection of gaze information? Fourth, does variation in the activity in a scene influence gaze selection?

On the first question, the results were clear: Observers preferentially selected the eyes over other regions of a scene. This was evident both in terms of fixation proportions and initial fixation data. Fixation proportions revealed that for all task conditions—look, describe, and social attention—the eyes were fixated most frequently, followed by heads, bodies, background, and finally other objects. Thus, the preferential bias for the eyes of a person persists in real-world scenes containing other body parts and objects. That said, it is also clear that eyes did not entirely dominate observers' attention in these scenes, as fixations did frequent ($M = 0.38$) other body parts and objects in the visual scenes. Finally, the initial fixation data supported observers' overall preferential bias for gaze information, with participants more likely to initially fixate the eyes and heads than any other region.

The second question we investigated was whether task would impact the selection of gaze information. Based on the folk understanding that people select gaze information in order to understand the social attention of others, we had predicted that observers would fixate gaze stimuli more often in the social attention task than in the baseline look or describe tasks. The results supported this prediction. We found a higher fixation proportion for eyes in the social attention task than in the look or describe tasks. However, this task enhancement of gaze selection was not immediate, with the initial fixation being committed most often to the eyes and heads equally across tasks. This suggests that initially observers' attention was captured by the eyes and heads of people in the scene regardless of task, and that with time the social attention group looked more often at the eyes in order to complete their task. It should be noted, however, that we are not claiming that the eyes would be preferentially selected in *every* task. For instance, it is highly probable that the eyes would be fixated much less if the task were to memorize what the people in the scene were wearing (e.g., Yarbus, 1965/1967). However, a conclusion from the present study is that observers have a natural preference to select the eyes (look task), and that this preference is later enhanced when they are asked to infer the attentional states of people in the scene (social attention task) but not when they are asked to describe the scene (describe task).

Finally, we had speculated that Yarbus' (1965/1967) Repin study raised the possibility that increases in the social content of a scene, or the activity of a scene, would lead people to increase their fixations on the eyes in a scene. Our findings supported this prediction when both factors were co-varied. That is, when the social content of a scene was increased by adding more people to a scene *and* when there was activity within a scene, then there was a significant increase in the fixations committed to the eyes. Thus, our data confirms the validity of Yarbus' Repin study and resolves a number of longstanding concerns related to that study. Were Yarbus' data an artifact of people sharing knowledge of that particular Repin painting? No, apparently not, as the findings generalize to our very different and varied complex real-world scenes and across all task sets. Were the participants in the Repin study looking at the eyes or at the heads in Yarbus' study? Our data suggest that it was the eyes. And are these fixations on the eyes being driven by the social content or activity in the scene? Our study indicates that it is the interaction between these factors. It is our speculation that this interaction reflects the importance of gaze information for understanding social interactions, that is, actions within social situations. This interpretation is reinforced by our finding that participants fixate the eyes by far the most when the task is to describe the social attention within a scene.

It is worth noting that our present study suggests a subtle, yet potentially very powerful way to examine observers' sensitivity to changes in social content. For instance, it would be instructive to examine how people who are thought to have atypical social attention, such as individuals with autism, scan scenes with one versus many people; and how their exploration of these scenes is affected by the action within it. For instance, if individuals with autism are adverse to an increase in social content, as has recently been suggested by Dalton et al. (2005), then the clear prediction is that they will tend to look away from the eyes as people are added to a scene and their activity increases.

Another avenue that seems ripe for investigation is how the factors that impact the *selection* of gaze information influence the *shift of attention* to gazed-at locations and objects. A number of possibilities exist. One is that whatever factors drive people to select a gaze stimulus, once gaze is selected, people will tend to shift their attention—overtly or covertly, or both—to the gazed-at location. Such an outcome would be in keeping with the current thinking on social attention, which has focused largely on the allocation of attention to a gazed-at location, and has concluded that the shift is largely automatic (Friesen & Kingstone, 1998; Langton, O'Donnell, Riby, & Ballantyne, 2006). An alternative possibility, however, is that because social content and activity drive people to fixate the eyes, they will actually work *against* attention being shifted to where gaze is being directed. That is, when gaze stimuli are highly engaging, such as when a scene contains social action, observers will be less likely to disengage from the eyes and shift their attention to gazed-at locations. This outcome would dovetail with recent studies suggesting that many of the lab-based studies of social orienting to gaze direction have overestimated the impact of gaze direction on the orienting of spatial attention (see Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003). Specifically, these studies have shown that other directional cues, like arrows, will trigger shifts of attention that closely approximate the effect observed for eyes. The implication is that the eyes and other directional cues will trigger an orienting effect that appears to be automatic when the testing environment is highly impoverished. Whether eyes will trigger a similar effect when the environment is complex is very much an open and important research issue.

We began our report by observing that, in examining the effect that gaze stimuli have on the orienting of spatial attention, and the neural systems that may mediate these shifts, past studies of social attention have routinely preselected and isolated the eyes and face stimuli from all other body parts and objects within a scene. We noted that this research approach, while productive in its own right, failed to inform researchers whether gaze was selected preferentially in complex real-world social scenes. Nor did this work tell researchers what factors, if any, were critical to this selection process. The present study has taken several important steps on these issues. We have shown unequivocally that while people will fixate other body parts and nonbody objects that are depicted within complex visual scenes, their preferential bias is to fixate the eyes of others. Our data also suggest that gaze selection is driven by the goal to extract social attention information, and factors that may change the content of this information, such as changes in the number of people and activity level within a scene will in turn affect the degree to which gaze is selected. Our study has also resolved a number of longstanding issues that had undermined the original classic work of Yarbus. Finally, we have found that our investigation has broad implications for future investigations and theories of social attention.

REFERENCES

Bentin, S., & Golland, Y. (2002). Meaningful processing of meaningless stimuli: The influence of perceptual experience on early visual processing of faces. *Cognition*, *86*, B1–B14.

Birmingham, E., Bischof, W. F., & Kingstone, A. (in press). Social attention and real world scenes: The roles of action, competition, and social content. *Quarterly Journal of Experimental Psychology.*

Buswell, G. T. (1935). *How people look at pictures.* Chicago, IL: University of Chicago Press.

Campbell, R., Heywood, C. A., Cowey, A., Regard, M., & Landis, T. (1990). Sensitivity to eye gaze in prosopagnosic patients and monkeys with superior temporal sulcus ablation. *Neuropsychologia*, *28*, 1123–1142.

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., Goldsmith, H. H., et al. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, *8*(4), 519–526.

Dolan, R. J., Fink, G. R., Rolls, E., Booth, M., Holmes, A., Frackowiak, R. S. J., & Friston, K. J. (1997). How the brain learns to see objects and faces in an impoverished context. *Nature*, *389*, 596–599.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*, 509–540.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review*, *5*, 490–495.

Gibson, B. S., & Kingstone, A. (2006). Visual attention and the semantics of space: Beyond central and peripheral cues. *Psychological Science*, *17*, 622–627.

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, *12*, 360–365.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*, 131–134.

Kingstone, A., Smilek, D., Ristic, J., Friesen, C. K., & Eastwood, J. D. (2003). Attention researchers! It is time to take a look at the real world. *Current Directions in Psychological Science*, *12*, 176–180.

Kingstone, A., Tipper, C., Ristic, J., & Ngan, E. (2004). The eyes have it! An fMRI investigation. *Brain and Cognition*, *55*, 269–271.

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, *6*, 541–568.

Langton, S. R. H., O'Donnell, C., Riby, D. M., & Ballantyne, C. J. (2006). Gaze cues influence the allocation of attention in natural scene viewing. *Quarterly Journal of Experimental Psychology*, *59,* 2056–2064.

Perrett, D. I., Smith, P. A. J., Potter, D. D., Mistlin, A. J., Head, A. S., Milner, A. D., & Jeeves, M. A. (1985). Visual cells in the temporal cortex sensitive to face view and gaze direction. *Proceedings of the Royal Society of London, Series B*, *223*, 293–317.

Ristic, J., Friesen, C. K., & Kinsgtone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin and Review*, *9*, 507–513.

Ristic, J., Wright, A., & Kingstone, A. (2006). The number line effect reflects top-down control. *Psychonomic Bulletin and Review*, *13*, 743–749.

Smilek, D., Birmingham, E., Cameron, D., Bischof, W. F., & Kingstone, A. (2006). Cognitive ethology and exploring attention in real world scenes. *Brain Research*, *1080*, 101–119.

Tipples, J. (2002). Eye gaze is not unique: automatic orienting in response to uninformative arrows. *Psychonomic Bulletin and Review*, *9*, 314–318.

Yarbus, A. L (1967). *Eye movements and vision* (B. Haigh, Trans.). New York: Plenum Press. (Original work published 1965)