Inhibited head movements: A risk of combining phoning with other activities?

Abstract—Studies of cellular phone use while driving have attributed impaired performance to the distractions of conversation. We determined that holding an inactive phone to the ear reduces the probability of eccentric head positions, potentially indicating reduced ability to monitor the visual surround. This effect may constitute a risk of cellular phone use independent of conversation and peculiar to handheld models.

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Cellular phone conversations are often conducted in settings in which unexpected hazards may approach from the side. Because the range of the eyes within the head is only approximately ± 50 degrees, using vision to monitor the world for hazards requires a person to repeatedly turn the head.¹ Mechanical impediments to head rotation depress the propensity to make head movements.² We questioned whether handheld cellular phones exert similar effects that might constitute an unrecognized risk of these devices, one unrelated to distraction and hitherto unexplored in studies of the impact of phoning on driving safety. To answer this question, we investigated whether seated subjects reduce their propensity to maintain eccentric head positions when holding an inactive cellular phone to the ear.

Methods. Twenty-six subjects (10 women, 16 men, aged 22 to 64 years) were tested in the seated position in settings that featured unobstructed fields of view exceeding ± 90 degrees and fairly homogeneous distributions of objects that might attract a subject's visual attention. Horizontal position of the head with respect to the world was measured by a miniature heading sensor (3DM-G, Microstrain, VT) attached to the vertex of a conventional baseball cap worn by the subject. Sensor output was sampled at 50 Hz on a laptop computer, which logged each orientation value to a histogram spanning ± 180 degrees in 0.1-degree "bins."

Each experiment was divided into two 10-minute epochs in which the seated subject either did or did not hold an inactive cellular telephone to the preferred ear, as if to engage in a phone conversation. The order of the epochs was randomized. Subjects were instructed only to regard the world about them in a natural fashion.

Each experiment yielded two histograms representing the distribution of horizontal head-in-space orientation during each 10-minute epoch. Histograms were individually scaled so that the area under the curve was 1.0 and shifted so that the 50% point of the cumulative area under the curve coincided with the histogram's center (0 degrees) bin. Span of head orientation was initially quantified by the angular range of the histogram encompassing the central 90% of the area under the curve (head range). Additionally, we determined the effect of the phone on the

most eccentric head positions as follows: In the without-phone histogram, we determined the angles delimiting the left and right 5% extremes of the area under the curve. We found the total area lying outside the same boundary angles in the with-phone histogram and divided this value by 0.1 (the total area of the 5% flanking regions in the without-phone histogram). The resultant value (eccentric orientation propensity) expresses the change in probability of the head being found within the most eccentric 10% of the orientations the subject assumed in the without-phone condition. We also determined the analogous, separate measures of the alteration in probability on the side ipsilateral and contralateral to the phone. For instance, for the side on which the subject held the phone, we determined the area under the curve of the with-phone histogram for eccentricities outside the 5% probability point of the corresponding side of the without-phone histogram. We divided this area by 0.05 (the area under each 5% tail of the without-phone histogram) and expressed the ratio of areas as a percentage.

Results. Figure 1 shows the distribution of head orientation for the with-phone and without-phone conditions in one subject, and demonstrates that head orientations were more narrowly distributed in the with-phone condition. We summarized these plots by determining head range as described above. Figure 2 plots head range for the with-phone condition vs the without-phone condition for all 26 subjects. The majority of subjects fell below the superimposed equivalence line, indicating that eccentric head positions were less probable in the with-phone condition. Overall, head range averaged 77.6 ± 22.9 degrees in the without-phone condition and 59.1 ± 26.0 degrees in the with-phone condition (paired *t* test, *p* = 0.0002), an average reduction of approximately 24%.

The 24% value, however, understates the effect on eccentric head orientations. The head-range measure is dominated by the most common head orientations. Eccentric head positions may be particularly critical for detecting peripheral hazards, but being less common than central orientations, any reduction in their probability would have a proportionately smaller impact on head range. Accordingly, we devised a more sophisticated measure (eccentric orientation propensity), which focuses on changes in the likelihood of eccentric head orientations. Eccentric orientation propensity was reduced to an average of $58.7 \pm 47.6\%$ (range, 1.4% to 178.9%) in the with-phone condition, or an average 41.3% reduction in the time the head occupied the extreme orientations achieved in the unencumbered state.

When calculating the eccentric orientation propensity above, we combined the left and right directions of head rotation. We also considered the two directions separately, as it was conceivable that holding the phone would interfere preferentially with head movements directed toward or away from the side of the phone. Because we were concerned with answering the question of whether reductions in head range

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Figure 1. Head orientation histograms. Histograms obtained from one subject who viewed his surroundings without the phone (gray area) and with the phone held to the ear (solid line). Vertical dashed lines mark the eccentricities of the flanking 5% areas of the without-phone histogram.

were specific to the side on which the phone was held, we limited our analysis to the 23 subjects whose head range actually decreased while holding the phone. This analysis demonstrated that there was no consistent relationship between the change in head orientation probability and the side of the phone. Eccentric head orientations decreased on average to $49.3 \pm 53.3\%$ on the phone side and $48.2 \pm 72.5\%$ on nonphone side ($p = 0.957$, paired t test). Plots (not shown) of this percentage for the phone side vs the nonphone side exhibited a wide scatter on either side of the line marking a 1:1 ratio. Thus while there was no consistent asymmetry in the probability ratios, we cannot exclude the possibility that individual subjects exhibit asymmetries in the effect on head movements related to the side of the phone.

Discussion. To date, studies of cell phone safety have concentrated on the impact of phoning on driving. These studies have demonstrated that cellular phone use is associated with reduced awareness of salient visual stimuli, an effect that has been attributed to the cognitive burdens of maintaining a

Figure 2. Comparison of head ranges in the with-phone and without-phone conditions. Each data point represents one subject. Dashed line indicates a 1:1 ratio.

conversation.³⁻⁹ Ours is the first study to demonstrate an effect of phoning that is unlikely to be attributable to cognitive loading, as the cognitive demands of the with-phone and without-phone conditions were identical. The results suggest that combining handheld phone use with other activities may engender a risk related to reduced monitoring of the visual surround, independent of the degree to which a conversation is mentally taxing. One way the effect might arise is if the handheld phone engenders a subconscious awareness that moving the head would disturb the optimal relationship between the ear and receiver. In this case, our results may apply to other situations. For instance, a user of a hands-free phone with a poorly fitting earpiece might avoid rapid or large amplitude head movements because of a similar subconscious recognition that such movements could dislodge the earpiece.

Although previous studies^{5,8} concluded that the risks of handheld and hands-free phones are identical, our results might have predicted a greater risk of handheld phones due to suppression of head movements. There are several possible explanations as to why this result has not been obtained. First, the effect would be expected to have the greatest impact under conditions in which scanning the periphery is important, as in changing lanes or crossing intersections. Thus it would not have been observed in driving studies comparing the effects of different phone designs based on reactions to stimuli presented to central vision.^{5,7,10} Second, the tendency of conversation to narrow the span of visual attention^{4,9} (and thus restrict head range) could occlude the conversation-independent effect of the handheld phones. Third, reductions in the range of head movements could be compensated by an increase in the range of eye movements.

The current study was limited in two respects. First, since we did not assess eye movements, we can only hypothesize that holding a phone affects the span of visual exploration. Second, the degree to which the phenomenon we demonstrated during spontaneous viewing applies to the more structured task of driving is unknown. It is conceivable that the learned patterns of driving—for instance, the pattern of looking to the left and right when preparing to cross an intersection—would override the suppressive effects on head movements. However, it should be recognized that not all of the gaze-shifting sequences during driving are as strongly patterned as those associated with intersection crossing. Maintaining awareness of the visual surround while driving requires periodic glances to mirrors that are not occasioned by specific procedures, and these less stereotypic redirections of gaze may be more akin to the spontaneous shifts made by subjects in our experiment. Ultimately, the degree to which the effect we have demonstrated impacts driving performance needs to be explored in a driving simulator using relevant tasks.

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Figure. (A) Patient's drawing of her experience: the dark area is intended to represent her loss of vision in the right hemifield, and bright colors represent her visual hallucinations. (Although she drew the dark area slightly across the midline, on confrontational testing the area of visual loss was restricted to the right hemifield.) (B) Photograph of patient's eyeglasses, showing the cardboard masks she constructed to minimize light stimulation of her right visual fields (arrowheads). (C) FLAIR MRI demonstrates increased signal in the gray matter of the left occipital lobe, consistent with an ischemic stroke (arrow in enlarged region of interest). (D) T1 MRI with gadolinium shows gyriform enhancement consistent with subacute infarction (arrow in enlarged region of interest). (E) SPECT scan shows a focal region of hypoperfusion in the left occipital cortex.

Vivid visual hallucinations from occipital lobe infarction

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Infarction of the occipital pole causes homonymous hemianopia, and release hallucinations occasionally occur in the region of the field defect.^{1,2}

A 64-year-old woman developed acute right homonymous hemianopia with vivid hallucinations in the right visual field. She drew what she experienced, including colored pinwheels and lines at right angles (figure, A). Because light exacerbated the positive phenomena, she constructed a cardboard mask on her eyeglasses

to minimize light entering her right visual field (figure, B). FLAIR MRI demonstrated subtle signs of ischemic infarction of the left occipital pole (figure, C). T1 imaging with gadolinium showed gyriform enhancement in the same region (figure, D). Focal hypoperfusion was evident on SPECT (figure, E). EEG was normal except for borderline slowing in the left occipital region.

The positive symptoms abated over a week. The hallucinations may have resulted from infarction, with disinhibition of higher visual centers, or from simple partial seizures not detected by surface EEG. The prolonged symptoms and finding of hypoperfusion by SPECT during the phenomena argue against an epileptiform etiology.

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