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Lights can reverse illusory directional hearing

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Abstract

Adding brief flashes of light to a train of auditory clicks [R. Hari, Illusory directional hearing in humans, Neurosci. Lett. 189 (1995) 29–30] can alter the sounds perceived location within the head. In an experimental procedure adopted from Hari [R. Hari, Illusory directional hearing in humans, Neurosci. Lett. 189 (1995) 29–30], 16 observers listened over headphones to 8 binaural clicks (i.e., 4 left-ear leading followed by 4 right-ear leading) separated by one of three ISIs (8, 64 and 120 ms), then reported the perceived location of each click-pair within the head. Flashing a light rightward across a CRT screen during temporally coincident click-pairs made observers report the location of the sounds in roughly equally spaced steps from left-to-right through the head. In contrast, light flashes originating on the right of the CRT and moving leftward reversed the perceived location of the clicks, so that the sound appeared to originate on the right side of the head and shift leftward. These effects were diminished when the first four lights were all presented on one side of the CRT and the last four lights were all presented on the other side of the CRT. This multimodal phenomenon occurs although the light was perceived external to the head while the sounds presented over headphones were perceived within the head.

Keywords: Directional hearing; Multisensory perception; Illusion; Space

Hari [4] had subjects listen to a train of 8 click-pairs where the interaural time interval of each click-pair was 0.8 ms, so that clicks 1–4, when presented in isolation were perceived as coming from the left side (i.e., 4 left-ear leading) and clicks 5–8 were perceived as coming from the right side (i.e., 4 right-ear leading). When ISIs between each click-pair were short (e.g., between 30 and 90 ms) observers perceived each subsequent click-pair to traverse a roughly equal percentage of space within the head, while longer ISIs (e.g., between 150 and 500 ms) made them report the four left-leading click-pairs as originating from closer to the left ear and the four right-leading click-pairs as originating from closer to the right ear. In essence, the location shift between the fourth and fifth click-pairs with shorter ISIs changed the perception of the entire train of clicks, implying that early click-pairs could be influenced by later click-pairs. This sluggishness is with an inter click-pair ISI of greater than 120 ms, which Hari [4] designated to be a minimum temporal window of neural integration.

Using Hari's [4] shorter range ISIs (e.g., 8, 64 and 129 ms), we hypothesized that adding a brief (i.e., 8 ms) flash of light to each of the auditory click-pairs could also alter the clicks perceived location. We predicted that flashing the lights across a CRT in the same direction as the clicks (i.e., having each subsequent light flash more rightward) would produce equally spaced perceived click locations compared with a flashing light condition where the first four lights flashed in the same far left position and the last four lights flashed in the same far right position. In contrast, flashing the lights across the CRT in the direction opposite to the clicks (i.e., having each subsequent light flash more leftward) would reverse the perceived click locations. Again, this condition would produce equally spaced perceived click locations compared with a flashing light condition where the first four lights flashed in the same far right position and the last four lights flashed in the same far left position.

Sixteen observers (9 females, 7 males, age range 18–22 years old) obtained from the undergraduate psychology research pool at Wake Forest University, with self-reported normal hearing and self-reported normal or corrected-to-normal vision, ran in each of four conditions. The experiment was

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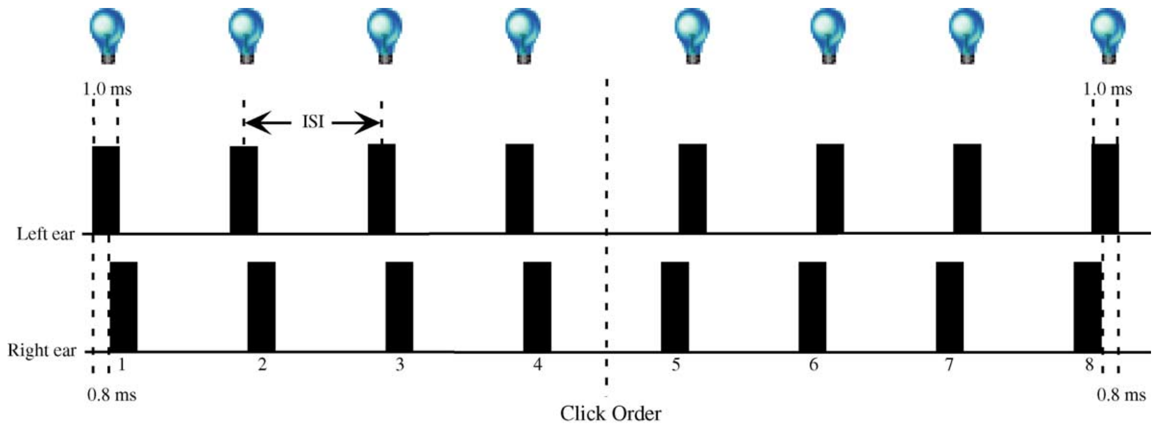

Fig. 1. Temporal sequence of auditory click-pairs, as designed by Hari [4] and flashing lights.

conducted in accordance with the Declaration of Helsinki and all procedures were carried out with the adequate understanding and written consent of the observers.

Adopting the experimental procedure of Hari [4], we had observers listen to a set of 8 click-pairs presented by E-Prime software over circumaural headphones (Koss; Pro/4AA; ∼50 dB A at peak measurement) with a randomly assigned inter-pair ISIs of either 8, 64, or 120 ms. Using various ISIs replicates Hari's [4] work, where these brief ISIs all produced the illusion of clicks traveling through the head. We preferred this procedure to fixed ISIs, in that it more closely replicates Hari's [4] results and demonstrates our strong findings across a number of short ISIs. We averaged our results across these brief intervals for the sake of brevity since it did not introduce significantly more variance to our results, which compare moving versus stationary lights. Each of the first 4 click-pairs consisted of a click first to the left ear followed 0.8 ms later by a click to the right ear. Each of the second 4 click-pairs reversed this order, with the right ear click leading the left. Each click-pair was accompanied by an 8 ms flash of light (96 cd/m^2, 1.3° radius) placed at various locations along a horizontal meridian on a CRT screen (Fig. 1).

After each train of click-pairs, we again adopted Hari's [4] experimental procedure and had observers report a number between 0 and 20 to designate the perceived location within their head of each click-pair. "0" represented the leftmost side of their head, "20" represented the rightmost side of their head, and "10" represented the middle of their head. In that there were no systematic differences across ISIs each observer's perceived click localization was first averaged across ISIs and then grand-averaged over the 16 observers for each of four conditions. Error bars represent the S.E.M. and indicate across-observer variability.

On randomly assigned trials (two blocks of 6 trials per ISI per condition) the flashing light either (a) moved across the CRT screen at ∼4.7° spatial intervals from left-to-right between two central fixation lines, or (b) the flashing light moved across the CRT screen in the direction opposite of (a), that is, from right-to-left, or (c) it remained on the extreme left of the CRT for the first four click-pairs and on the extreme right of the CRT for the last four click-pairs, or (d) it remained on the extreme right of the CRT for the first four click-pairs and on the extreme left of the CRT for the last four click-pairs. This produced a total of 144 trials per observer. The entire experiment took less than 1 h.

Fig. 2 shows that when the 8 flashes sequentially flashed left-to-right across the CRT the sound appeared to traverse through the head in roughly equal steps (filled diamonds). This is similar to what Hari [4] found for short ISIs. However, when the 8 lights sequentially flashed right-to-left across the CRT, the sound initially appeared right of midline and in roughly equal steps ended up just left of midline (filled squares).

Fig. 3 shows that when the flashes were grouped 4-left side then 4-right side the sound appeared grouped as 4-left/4-right (at ∼3 and ∼17; open diamonds). This is similar to what Hari [4] found for long ISIs. In contrast, when the flashes

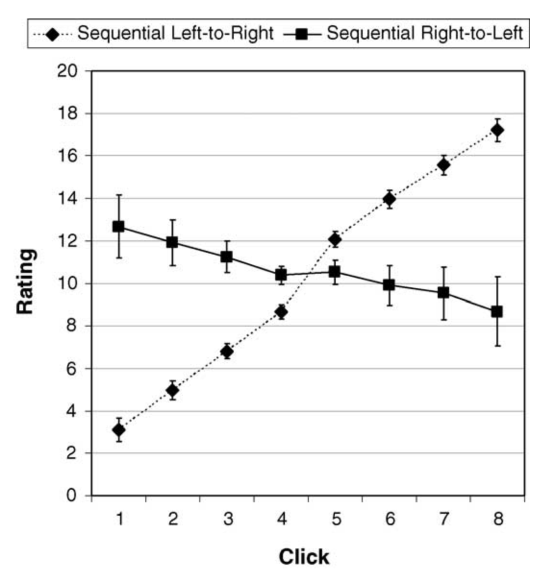

Fig. 2. Perceived location of clicks when sequential lights flash across a CRT: left-to-right (closed diamonds) and right-to-left (closed squares).

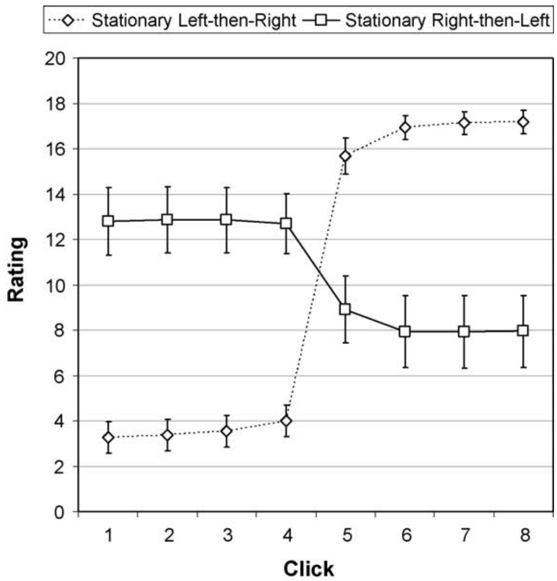

Fig. 3. Perceived location of clicks when: 4 lights flash left then 4 lights flash right (open diamonds) and 4 lights flash right then 4 lights flash left (open squares).

were grouped 4-right side then 4-left side the locations of the sound pattern flipped directions but were less extreme (being ∼13 and then ∼8; open squares).

Hari [4] showed that short ISIs made observers perceive each subsequent click-pair to traverse a roughly equal percentage of space within the head, while longer ISIs made them report the four left-beginning click-pairs as more extreme left and the four right-beginning click-pairs as more extreme right.

In the present experiment, flashing lights leftward across a CRT screen during temporally coincident click-pairs made observers report the location of the sounds in roughly equally spaced steps from left-to-right. In contrast, rightward clicks reversed this rating scale range. However, in this case the range was contracted. This multimodal effect occurs even though the light was perceived to be external to the head while the headphone sounds were perceived to be within the head. This is important in that Spence [8] has shown that even small lateral discrepancies (of as little as 3°) between the locations of auditory and visual stimuli can lead to a dramatic reduction, or even elimination, of crossmodal attentional effects. However, with our audiovisual interaction the visual stimuli were able to dominate the auditory percept. This, of course, is contingent upon the saliences of the stimuli used, since such relative dominances typically depend on the relative saliences of the stimuli.

When the lights are stationary (i.e., 4 far left then 4 far right or vice versa), the perceived locations appear to be farther left or farther right than when the lights were moving. This stationary condition produces results that are more like Hari's [4] long (e.g., 150–250 ms) ISI conditions.

Previous research involving apparent motion has shown that a properly timed visual stimulus can influence auditory apparent motion [1,7]. Apparent motion is important in that this is how these click-pairs sound (especially those at 8 and 64 ms ISIs). Moreover, final auditory target position tends to be located as displaced in the direction of perceived motion [3]. This is similar to our findings. It is also important to note that previous related work exploring visual capture has shown that eye movements are not a prerequisite for misperceived auditory direction [6], and are not thought to be a factor in the current study in that it was easy to maintain stable central fixation, and conditions were randomly presented.

We have no reason to evoke a higher-level (e.g., cognitive) interpretation for our findings because clicks and lights have no intrinsic reason to be cojoined. That is, they have no higher-level (e.g., linguistic) associations as one has in the ventriloquism effect [2], or as with the sound of a kettle whistle while viewing steam rising from a boiling kettle [5]. Moreover, as in Bertelson and Radeau's [2] first experiment, our lights bias sounds without the possibility of what they call 'perceptual fusion' (i.e., the percept that both the visual and auditory signal originate from the same location in space). We thus consider our finding to be a more primitive raw perceptual effect.

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