strate the approximate settling equivalence of large pumice and lithics in that W_b/W_l is generally near unity. As we noted in our paper, low values of the ratio near the vent probably reflect the scarcity of large pumice in the initial suspension.

W. Brian Dade
Herbert E. Huppert
Institute of Theoretical Geophysics,
Department of Earth Sciences,
and Department of Applied Mathematics & Theoretical Physics,
University of Cambridge,
Cambridge CB2 3EQ, UK

1. Dade, W. B. & Huppert, H. E. *Nature* **381**, 509–512 (1996).
2. Wilson, C. J. N. *Phil. Trans. R. Soc. Lond. A* **314**, 229–310 (1985).
3. Sparks, R. S. J. *Sedimentology* **23**, 147–188 (1976).
4. Walker, G. P. L., Wilson, C. J. N. & Froggatt, P. C. *J. Volcanol. Geotherm. Res.* **9**, 409–421 (1981).
5. Walker, G. P. L., Self, S. & Froggatt, P. C. *J. Volcanol. Geotherm. Res.* **10**, 1–11 (1981).
6. Wilson, C. J. N. *J. Volcanol. Geotherm. Res.* **20**, 55–84 (1984).
7. Druitt, T. H. *J. Volcanol. Geotherm. Res.* **65**, 27–39 (1985).
8. Baines, P. G. *Topographic Effects in Stratified Flows* (Cambridge Univ. Press, 1995).

Sound alters visual motion perception

Little is known about how complementary inputs from different senses are coordinated. To explore the perceptual consequences of this coordination, we devised simple visual stimuli whose analogues outside the laboratory ordinarily produce distinctive sounds. Our assay, optimized with visual stimuli whose motion could be seen in either of two ways[1], reveals that sound can alter the visual perception of motion.

A computer displayed two identical objects that moved steadily towards one another, coincided, and then moved apart. This display is consistent with two different interpretations: either, after coincidence, the two objects could have continued in their original directions; or they could have collided and then bounced, reversing directions. Collisions often produce sounds characteristic of the materials and force of the impact[2]. Our experiments determined whether introduction of sounds would promote the perception of bouncing.

The targets, small disks, moved in three different ways. In two conditions the disks paused at the point of their coincidence, for either one frame or two. In another condition the disks moved continuously with no interruption. These visual conditions were presented together with a brief click (2.5 ms; sound pressure level 75 dB) either 150 ms before or after coincidence, or at the point of coincidence. A control condition presented no sound. Each stimulus combination was presented 20 times in random order to ten naive observers. After each trial, the observer reported whether the disks appeared to stream through or bounce off each other.

Sound at or near the point of coincidence promotes perception of 'bouncing' compared with the control condition (see Fig. 1; repeated measures analysis of variance, $P < 0.0001$). A sound just before visual coincidence has nearly as much effect as a sound at coincidence, but a sound after coincidence has significantly less effect ($P < 0.01$), although it still enhances the perception of bouncing. There is considerable tolerance for asynchrony between sound and visual inputs: even when the sound is delayed by 150 ms after coincidence, the likelihood of seeing bouncing increases ($P < 0.05$). As others have reported[3,4], the overall proportion of bouncing responses grows with increasing pause duration ($P < 0.001$).

The effect of sound on visual motion could represent some generalized attention effect, evocable by any salient transient. We examined this possibility by testing three conditions with 15 new observers. In one condition, a sound (440 Hz, 100 ms, 80 dB) came on only at the point of coincidence. In another condition the same sound, equally intense, was on for the entire visual display, but was turned off for 100 ms at the moment of coincidence. In the final condition no sound was presented. As before, sound onset significantly increased bouncing reports ($P < 0.01$). However, sound offset produced results indistinguishable from those with no sound at all. This suggests that the sound's impact on visual motion is not the product of heightened attention at the moment of coincidence, but may require an acoustic event that signals a collision between moving objects.

The origin of the effect of sound on visual motion is unknown; it may involve some form of multisensory cells[5] and/or feedback from higher-level, multisensory areas onto primary motion areas[6]. Research combining psychophysics and brain imaging may reveal the nature of this effect, and of audiovisual interactions more generally.

Robert Sekuler
Volen Center for Complex Systems,
Brandeis University,
Waltham, Massachusetts 02254, USA
e-mail: sekuler@volen.ccs.brandeis.edu
Allison B. Sekuler
Department of Psychology,
University of Toronto, Toronto,
Ontario M5S 3G3, Canada
Renee Lau
Dana Hall School,
Wellesley,
Massachusetts 02181, USA

1. Metzger, W. *Psychol. Forsch.* **19**, 1–49 (1934).
2. Gaver, W. W. *Ecol. Psychol.* **5**, 1–29 (1993).
3. Bertenthal, B. I., Banton, T. & Bradbury, A. *Perception* **22**, 193–208 (1993).
4. Sekuler, A. B., Sekuler, R. & Brackett, T. *Invest. Ophthalmol. Vis. Sci.* **36**, S50 (1995).
5. Sparks, D. L. & Groh, J. M. in *The Cognitive Neurosciences* (ed. Gazzaniga, M. S.) 565–583 (MIT Press, Cambridge, MA, 1995).
6. McIntosh, A. R., Cabeza, R., Lobaugh, N. & Houle, S. *Soc. Neurosci. Abstr.* **22**, 718 (1996).

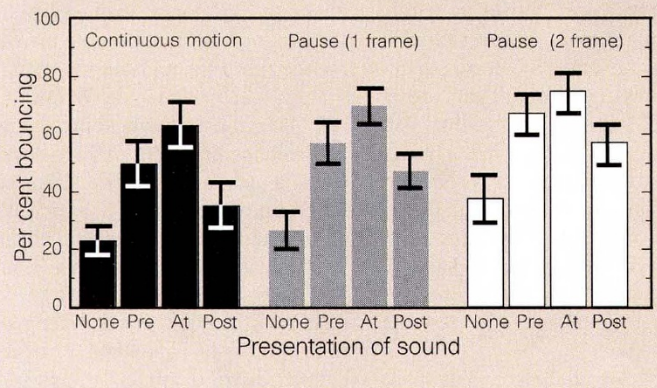

Figure 1 **Percentage of reports of stimulus bouncing. In each trial, two brown disks (visual angle 0.5°, 3.5 cd m^{-2}) appeared on opposite sides of a computer display (white, 95 cd m^{-2}). Initially separated by 4.2°, the disks moved at 6° per s, coincided, then continued across the display. The trial ended when each disk had reached the other's starting position, and both disks disappeared from view (1.4 s). The sequence was viewed binocularly from a distance of 114 cm. Observers indicated whether the disks appeared to stream through or bounce off one another. Black bars, disks moved continuously; grey, one-frame and white, two-frame pause. Motion was accompanied by a brief sound 150 ms before (Pre) or after (Post) the disks coincided, or at the moment of coincidence. On one quarter of the trials, no sound was presented (None). Error bars, ±s.e.m. Full details of methodology and other results available on request from R. S.**