Supporting Information

Sievers et al. 10.1073/pnas.1209023110

SI Text

Data. Spreadsheets containing the raw data are attached. Dataset S1 includes all of the data from the United States experiment. Dataset S2 includes all of the data from the Kreung experiment, as well as discretized data from the United States experiment. The raw means by emotion are provided in Table S1, for each population. Table S2 provides the *z*-scored means of the discrete data by Emotion, Slider, and Population (corresponding to the cross-cultural ANOVA). These means were *z*-scored within each slider (using discrete data), for each population separately. These means are graphically portrayed in Fig. S1.

Fisher's Linear Discriminant Analysis. In an attempt to estimate which sliders were most important to the emotion categorization effect, we performed a Fisher's linear discriminant analysis between the slider values and their associated emotions for each population, for each modality. The numbers represent the importance of each feature (slider) in distinguishing the given emotion from all of the other emotions (higher numbers mean more importance). These data are presented in Table S3.

In the United States data, consonance was the most effective feature for discriminating each emotion from the other four emotions in both modalities, accounting for ~60% of the total discrimination between emotions. The second most effective feature was direction (up/down), accounting for 26% (music) and 35% (movement). In the Kreung music data, rate and step size were most effective for discriminating each emotion compared with the other four; rate and consonance were most effective for the Kreung movement data.

It is important to note that low discriminant values do not necessarily imply unimportance for two reasons. First, this analysis only reveals the importance of each feature as a discriminant for each emotion when that emotion is compared with the other four emotions. That is, any other comparison (e.g., each emotion compared with a different subset of emotions) would yield different values. For example, although jitter may seem relatively unimportant for discriminating emotions based on the data in Table S3, jitter was a key feature for discriminating between particular emotion dyads (e.g., "scared" vs. "sad" in the United States data). Second, whether a parameter (slider) was redundant in this dataset is impossible to conclude because of potential interactions between parameters. Additional research is necessary to determine whether one or more features could be excluded without significant cost to emotion recognition. Such research would benefit from testing each feature in isolation (e.g., by holding others constant) to better elucidate its contribution to emotional expression within and across modalities and cultures.

Multimedia. Audio and visual files of the emotional prototypes for both music and movement in the United States and Kreung experiments are available as Audios S1, S2, S3, S4, S5, S6, S7, S8, S9, and S10, and Movies S1, S2, S3, S4, S5, S6, S7, S8, S9, and S10. Each file contains three sequential probabilistically generated examples based on the prototype settings as explained in the cross-cultural Euclidean distance analysis.

Detailed Methods. Our computer program was created using Max/MSP (1), Processing (2), and OpenGL (3). Subjects were presented an interface with slider-bars corresponding to the five dimensions of our statistical model: rate (in beats per minute or BPM), jitter (SD of rate), consonance/visual spikiness, step size, and step direction. The five sliders controlled parametric values fed to an algorithm that probabilistically moved the position of a marker around a discrete number-line in real time. We will refer to the movements of this marker as a path. The position of the marker at each step in the generated path was mapped to either music or animated movement.

The number-line traversal algorithm can be split into two parts. The first part, called the metronome, controlled the timing of trigger messages sent to the second part, called the path generator, which kept track of and controlled movement on the number line. The tempo and jitter parameters were fed to the metronome, and the consonance, step size, and step direction parameters were fed to the path generator. When the subject pressed the space bar on the computer keyboard, the metronome turned on, sent 16 trigger messages to the path generator (variably timed as described below), and then turned off. The beginnings and endings of paths correspond to the on and off of the metronome.

Tempo was constrained to values between a minimum of 30 BPM and a maximum of 400 BPM. Jitter was expressed as a coefficient of the tempo with a range between 0 and 0.99. When jitter was set to 0, the metronome would send out a stream of events at evenly spaced intervals as specified by the tempo slider. If the jitter slider were above 0, then specific per-event delay values were calculated nondeterministically as follows. Immediately before each event, a uniformly random value was chosen between 0 and the current value of the jitter slider. That value was multiplied by the period in milliseconds as specified by the tempo slider, and then the next event was delayed by a number of milliseconds equal to the result. These delays were specified on a per-event basis and applied to events after they left the metronome. No event was delayed for longer than the metronome period. This per-event delay was essentially a shifting or "sliding" of each event in the stream toward—but never past—the next note in the stream. Each shift left less empty space on one side of the note's original position and more empty space on the other. This process ensured that tempo and jitter were independent. The effect was that as the value of the jitter slider increased, the precise timing of event onsets became less predictable but the mean event density remained the same.

The path generator can be conceived of as a "black box" with a memory slot, which could store one number and which responded to a small set of messages: reset, select next number, and output next number. Whenever the path generator was sent the reset message, a new starting position was picked and stored in the memory slot (the exact value of the starting position was constrained by the value of the scale choice slider as explained below). Whenever the path generator was sent the select next number message, it picked a new number according to the constraints specified by the slider bars: first, the size of the interval was selected, then the direction (up or down), then a specific number according to the position of the scale choice slider. The output next number message caused the path generator to output the next number to the music and motion generators, described below.

When selecting a new number, the path generator first chose a step size, or the distance between the previous number (stored in the memory slot) and the next. This value was calculated nondeterministically based on the position of the step size slider. The step size slider had a minimum value of 0 and a maximum value of 1. When choosing a step size, a uniformly random number between 0 and 1 was generated. This number was then used as the x value in the following equation, where a = the value of the step size slider:

$$r = \begin{cases} \frac{1-a}{-a} \cdot x + 1 & x \le a \\ \frac{-a}{1-a} \cdot (x-1) & x > a \end{cases}$$

The result r was multiplied by 4 and then rounded up to the nearest integer to give the step size of the event. As the value of the step size slider increased, the likelihood of a small step size decreased, and vice versa. If the slider was in the minimum position, all of the steps would be as small as possible. If it was in the maximum position, all of the steps would be as large as possible. If it was in the middle position, there would be an equal likelihood of all possible step sizes. Other positions skew the distribution one way or the the other, where higher values resulted in a larger average step size. Note that these step size units did not correspond directly to the units of the number line; they were flexibly mapped to the number line as directed by the setting of the consonance parameter, as described below.

After the step size was chosen, the path generator determined the direction of the next step: up or down. As with step size, the step direction was calculated nondeterministically based on the position of the step direction slider. The step direction slider had a minimum value of 0 and a maximum value of 1. When choosing step direction, a uniformly random number between 0 and 1 was generated. If that number was less than or equal to the value of the step direction slider, then the next step would be downward; otherwise the next step would be upward.

Finally, the number was mapped on to one of 38 unique scales. As the notion of a scale is drawn from Western music theory, this decision requires some elaboration. In Western music theory, a collection of pitches played simultaneously or in sequence may be heard as consonant or dissonant. The perception of a given musical note as consonant or dissonant is not a function of its absolute pitch value, but of the collection of intervals between all pitches comprising the current chord or phrase. The relationship between interval size and dissonance is nonlinear. For example, an interval of seven half steps, or a perfect fifth, is considered quite consonant, whereas an interval of six half steps, or a tritone, is considered quite dissonant. Intervallic distance, consonance/dissonance, and equivalency are closely related. If a collection of pitch classes x (a pitch class set, or PC set) has the same set of intervallic relationships as another PC set y, those two PC sets will have the same degree of consonance and are transpositionally identical (and in certain conditions equivalent).

Absolute pitches also possess this property of transpositional equivalency. When the frequency of a note is doubled, it is perceived as belonging to the same pitch class. For example, the A key closest to the middle of a piano has a fundamental frequency of 440 Hz, but the A an octave higher has a fundamental frequency of 880 Hz; both are heard as an A. Western music divides the octave into 12 pitch classes, called the chromatic scale, from which all other scales are derived. Because we wanted to investigate musical dissonance and possible functional analogs in the modality of motion, our number-line scales were designed to be analogous to musical scales, where a number-line scale is a five-member subset of the chromatic set [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. There are 768 such subsets of the chromatic set, many of which are (in the domain of music) transpositionally or inversionally equivalent. Our scale list was created by generating the prime forms of these 768 subsets and then removing duplicates, yielding 38 unique scales (4). These scales were ordered by their aggregate dyadic consonance (5).

The algorithm for generating a specific path across the number line was as follows. The number line consisted of the integers from 0 to 127 inclusive. When the algorithm began, three variables were stored. First, a starting-point offset between 0 and 11 was selected uniformly at random, then an octave bias variable was set to 5, and a scale position variable was set to 0. The starting-point offset was used to ensure that each musical phrase began on a different, randomly selected note, ensuring that no single context-determining "tonic" pitch or "root" scale degree could be identified on the basis of repetition. The current scale class was determined by using the scale position variable as an index to the array of scale elements specified by the position of the scale slider. For example, if the current selected scale was [0, 3, 4, 7, 10] and the current scale position variable was 2, then the current scale class would be 4 (indices start from 0). The current position on the number line was given by multiplying the octave bias by 12, adding the starting-point offset, and then adding the current scale class value. For example, if the octave bias was 5, the starting-point offset was 4, and the scale class value was 7, then the current position on the number line would be 71.

When the select next number message was received, an interval and note direction were selected as described above. If the note direction was upward, then the new scale position value was given by the following:

$$(\text{current scale position} + \text{new interval value})\%\ 5$$

If the note direction was downward, then the new scale position value was given by:

$$5 + (\text{current scale position} - \text{new interval value})$$

Either of these conditions may imply a modular "wrapping around" the set of possible values (0–4). If this is the case, then the current octave variable is either incremented by 1 in the case of an upward interval, or decremented by 1 in the case of a downward interval. If a step in the path would move the position on the number line outside of the allowed range, 12 would be either added to or subtracted from the new position. This finding means that when the upper or lower boundaries of the allowed pitch range were hit, the melody would simply stay in the topmost or bottommost octave, flattening out the overall pitch contour at the extremes. This process could result in occasional upward melodic intervals at the bottommost extreme or downward melodic intervals at the topmost extreme, despite the setting of the pitch direction slider. In practice, this rarely occurred, and was confined to the more extreme "angry" emotional expressions where pitch direction was maximally downward and step size was maximally large.

The subjects were divided into two groups. For the first group, number-line values were mapped to musical notes, and for the second group, number-line values were mapped to animated movement.

Our mapping from movement across a number-line to Western music was straightforward, as its most significant modality-specific features were taken care of by the very design of the number-line algorithm. The division of pitches into pitch-classes and scales is accounted for by the scale-class and scale selection system used by the algorithm, as is the modulo 12 equivalency of pitch-classes. Each number was mapped to a specific pitch which was sounded as the algorithm selects the number. The number 60 was mapped to middle C, or C4. Movement of a distance of 1 on the number line corresponded to a pitch change of a half-step, with higher numbers being higher in pitch. For example, 40 maps to E2, 0 maps to A0, and 127 maps to G9. Notes were triggered via MIDI and played on the grand piano instrument included with Apple GarageBand.

Mapping from movement across a number-line to animated movement was less straightforward. Our animated character was a red ellipsoid ball with cubic "eyes" (Fig. S2). The ball sat atop a rectangular dark gray "floor" on a light gray background. An ellipsoid was chosen because it can be seen as rotating around a center. The addition of eyes was intended to engage cognitive processes related to the perception of biological motion. We wanted our subjects to perceive the ball as having its own subjectivity, that it could be capable of communicating or experiencing happiness, sadness, and so forth. The movement of our character (henceforth referred to as "the Ball") was limited to bouncing up and down, rotating forward and backward, and modulating the spikiness of its surface. Technical details follow.

The Ball was drawn as a red 3D sphere composed of a limited number of triangular faces, which were transformed into an ellipsoid by scaling its y axis by a factor of 1.3. The Ball was positioned such that it appeared to be resting on a rectangular floor beneath it. Its base appeared to flatten where it made contact with the floor. The total visible height of the Ball when it is above the floor was 176 pixels; this was reduced to 168 pixels when the Ball was making contact with the floor. Its eyes were small white cubes located about 23% downward from the top of the ellipsoid. The Ball and the floor are rotated about the y axis such that it appeared the Ball was looking somewhere to the left of the viewer.

Every time the current position on the number line changed, the Ball would bounce. A bounce is the translation of the Ball to a position somewhere above its resting position and back down again. Bounce duration was equal to 93% of the current period of the metronome. The 7% reduction was intended to create a perceptible "landing" between each bounce. Bounce height was determined by the difference between the current position on the number line and the previous position. A difference of 1 resulted in a bounce height of 20 pixels. Each additional addition of 1 to the difference increased the bounce height by 13.33 pixels (e.g., a difference of 5 would result in a bounce height of 73.33 pixels). The Ball reached its translational apex when the bounce was 50% complete. The arc of the bounce followed the first half of a sine curve.

The Ball would rotate, leaning forward or backward, depending on the current number line value. High values caused the Ball to lean backward, such that it appeared to look upward, and low values caused the Ball to lean forward or look down. When the current value of the number line was 60, the Ball's angle of rotation was 0°. An increase of 1 on the number line decreased the Ball's angle of rotation by 1°; conversely, a decrease of 1 on the number line increased the Ball's angle of rotation by 1°. For example, if the current number-line value were 20, the Ball's angle of rotation would be 40°. If the current number-line value were 90, the Ball's angle of rotation would be −30°.

The Ball could also be more or less "spiky." The amplitude of the spikes or perturbations of the Ball's surface were analogically mapped to musical dissonance. The visual effect was achieved by adding noise to the x, y, and z coordinates of each vertex in the set of triangles comprising the Ball. Whenever a new position on the number-line was chosen, the aggregate dyadic consonance of the interval formed by the new position and the previous position was calculated. The maximum aggregate dyadic consonance was 0.8, the minimum was −1.428. The results were scaled such that when the consonance value was 0.8, the spikiness value was 0, and when the consonance value was −1.428, the spikiness value was 0.2. Changes in consonance of 0.01 resulted in a change of 0.008977 to the spikiness value. For each vertex on the Ball's surface, spikiness offsets for each of the three axes were calculated. Each spikiness offset was a number chosen uniformly at random between −1 and 1, which was then multiplied by the Ball's original spherical radius times the current spikiness value.

For the emotion labels care was taken to avoid using words etymologically related to either music or movement (e.g., "upbeat" for "happy" or "downtrodden" for "sad"). See Fig. S3*A* for a screen shot of the United States experiment interface and the lists of emotion words presented to participants.

In the United States experiment, the labels for the slider bars changed between tasks as described in Fig. S3*B*. In the Kreung experiment, slider bars were not labeled in the music task, and were accompanied by icons in the movement task. See Fig. S4 for a screenshot of the slider bars during Kreung movement task.

To confirm or reject the presence of a cross-cultural code, it needed to be possible for Kreung participants to select slider-bar positions that would create music and movement similar to that created by the United States participants. For this reason, the discretization values for the Kreung slider bars were derived from the United States data. These values are shown in Table S4.

For consonance, the extreme low value of 4 was chosen by taking the midpoint between the median consonance values for "angry" and "scared." The extreme high value of 37 was the midpoint between the median values for "happy" and "peaceful." The central value of 30 was chosen by taking the median value for "sad," which was neither at the numeric middle nor either of the endpoints. The values for the other sliders were selected similarly, with two exceptions: For rate, for which there was no emotion sitting reliably between the high and low extremes, the numeric middle between the extremes was chosen as the central value. For direction, because the values for "happy" and "peaceful" clustered around the center of the scale, the ideal center (50, neither up nor down) was chosen as the central value.

Although this discretization did limit the number of possible settings of the slider bars, it did not substantially encourage the Kreung participants to use the same settings as the United States participants. With three possibilities for each of five slider bars, there were 3^5 or 243 possible settings available per emotion, with only one of those corresponding to the choices of the United States participant population. That is, for each emotion, there was a 0.4% chance the prototypical United States configuration would be chosen at random.

In the United States experiment the sliders were automatically set to random positions at the beginning of each session. In the Kreung experiment, with discretized sliders with three values per slider, all of the sliders were set in the most neutral, middle position. Subjects could press a button (the space bar on the computer keyboard) to begin a melody or movement sequence. The sliders could be moved both during and between sequences. The duration of each sequence was determined by the tempo setting of the slider. When moved during a sequence, the melody/ball would change immediately in response to the movements. Between music sequences, there was silence. Between movement sequences, the ball would hold still in its final position before resetting to a neutral position at the beginning of the next sequence.

Slider Bar Reliability for Kreung Data. The discrete nature of the Kreung data afforded χ^2 analyses to quantify the likelihood that parameters (sliders) were used randomly. The values in Table S5 indicate the likelihood that the distributions of slider positions in the Kreung data were because of chance (lower values indicate lower likelihood of random positioning). As can be seen, the rate slider was used systematically (nonrandomly) for all emotions, across modalities. Other sliders varied in their reliability by emotion but were used nonrandomly for subsets of emotion.

L'ak and Modernization. L'ak, the village where we conducted our study, had no infrastructure for water, waste management, or electricity, although it was equipped with a gas-powered generator. The Kreung language is not mutually intelligible with Khmer, Cambodia's official language, and has no writing system. L'ak and nearby villages maintain their own dispute resolution practices separate from the Cambodian legal system. The Kreung practice an animist religion and have maintained related practices such as speaking with spirits and ritual animal sacrifice (6). Access to the village is limited by its remote location and the difficulty of travel on unmaintained dirt roads, which require a four-wheel drive vehicle and are impassable much of the year because of flooding. Almost none of the Kreung participants could speak or read Khmer, so communication was facilitated by an English-Khmer translator who worked in conjunction with a Khmer-Kreung translator who lived in the village.

Until large-scale logging operations started in Ratanakiri in the late 1990s, the tribal ethnic minorities in the area remained culturally isolated. The destruction of the forests made the traditional practices of slash-and-burn agriculture and periodic village relocation untenable, and the past decade has seen gradual, partial, and reluctant modernization (7). This modernization has been limited, and has not resulted in sustained contact with Western culture via television, movies, magazines, books, or radio.

We conducted a survey of our participants to determine the extent of their exposure to non-Kreung culture. The survey included age, sex, cell phone ownership, time spent talking or listening to music on cell phones, time spent watching television, and time spent speaking Khmer vs. speaking Kreung. Very few of the Kreung participants owned cell phones, and those that did reported spending very little time using them for listening to music. None of the Kreung participants reported having listened to Western music. However, some reported having watched videotapes of Thai movies that had been dubbed into Khmer for entertainment, and thus may have had passive exposure to Khmer and Thai music on video soundtracks. We should note again that most of our participants could not speak or understand Khmer.

We did not disqualify participants with passive exposure to Khmer and Thai music via videos for the following reasons: (*i*) Khmer and Thai music are not Western. Their traditions, instruments, styles of singing, tuning systems, and use of vertical harmony (if any) are substantially different from those in Western music, and so exposure to Khmer and Thai music would not acclimate our participants to Western musical conventions. (*ii*) Our computer program was not biased toward Western film music. The program excluded vertical harmony and systematic rhythmic variation, and included many more scales than the familiar Western major and minor modes. Ultimately, both the Kreung and Western participants frequently chose settings outside the bounds of Western cliché.

Music and Dance in Kreung Culture. In Kreung culture, music and dance occur primarily as a part of rituals such as weddings, funerals, and animal sacrifices (6). Kreung music and dance traditions have not been well documented. Interviews with Kreung musicians indicated that there is no formal standardization of tuning or temperament as is found in Western music, nor is there any system of vertical pitch relations equivalent to Western tonal harmony; Kreung music tends to be heterophonic in nature. Kreung musical instruments bear no obvious morphological relationship to Western instruments. Furthermore, although some Kreung and Khmer instruments are similar, most are profoundly different, and there is very little overlap between traditional Kreung music and that performed throughout the rest of Cambodia. The geographical isolation of the Kreung combined with the pronounced formal dissimilarity of Kreung and Western music made L'ak an ideal location for a test of cross-cultural musical universality.

We observed two musical forms in L'ak. First, a gong orchestra, where each performer plays a single gong in a prearranged rhythmic pattern, causing a greater melodic pattern to emerge from the ensemble, often accompanying group singing and dancing. Second was a heterophonic style of music based around a string instrument called the *mem*, accompanied by singing and wooden flutes. In this form, all players follow the same melodic line while adding loosely synchronized embellishments. The *mem* is an extremely quiet bowed monochord that uses the musician's mouth as a resonating chamber. Traditionally the *mem* is bowed with a wooden or bamboo stick, and its sound is described as imitative of buzzing insects. Kreung music is passed along by pedagogical tradition, and the role of musician is performed primarily by those who are highly skilled and extensively trained. Examples of the two forms of Kreung music described here are included in Audios S11 and S12. These recordings are courtesy of Cambodian Living Arts (www.cambodianlivingarts.org) and Sublime Frequencies (www.sublimefrequencies.com).

We found the Kreung data to be substantially noisier than the data collected in the United States. We speculate that some of this noise was related to unfamiliarity with the experimental context, as described in the main text. However, additional noise may have been the result of unfamiliarity with the tuning, timbre, and scales used in our program, none of which are native to Kreung culture.

Kreung-English Translation: "Happy" vs. "Peaceful." In the Kreung language there is no word that translates directly to "peaceful." After extensive conversation with our translators the closest words we could find were "*sngap*" and "*sngap chet*." Idiomatically, these translate to something like "still heart," which seemed to capture the essence of "peacefulness" we were looking for. However, "*sngap*" and "*sngap chet*" do not refer to emotion as a state of being, but instead refer to emotion as an active process. In particular, they refer to the process of having been angry and then experiencing that anger dissolve into happiness. For this reason, both words strongly connote happiness. Some of our subjects seemed to use these words as synonyms for happiness, occasionally even reporting they had completed expressing "happy" after being asked to express "peaceful," although never the other way around. The difficulty understanding the concept of peacefulness cross-culturally may be consistent with a previous finding in the literature that reported peacefulness as the least successfully identified emotion compared with "happy," "sad," and "scary" (8). Nevertheless, the Kreung results show a distinct difference between "happy" and "peaceful." "Peaceful" music and "peaceful" motion both tended to be substantially slower than their "happy" counterparts, a relationship matching the findings of the experiment in the United States.

Comment on Clynes and Nettheim. Clynes and Nettheim attempted to show cross-modal, cross-cultural recognition of emotional expressions produced in the domain of touch and mapped to sound (9). However, there are several important differences between their experiments and the one reported here. Clynes and Nettheim used a forced-choice paradigm and created individual touch-to-sound mappings per emotion, as opposed to using fixed rules representing hypotheses about the relationship between the two domains. Clynes's mapping decisions introduced intuitively generated, arbitrary pitch content specific to each emotion, suggesting what was being tested was not a cross-modal relationship, but simply the effect of pitch on emotion perception. Clynes proposes the idea of "essentic forms": fixed, short-time, essential emotional forms that are biologically determined and measured in terms of touch. Although this is interesting as a hypothesis, it is not confirmed by the available data (10), and is not a model of feature-based cross-modal perception.

Informed Consent in the Kreung Village. Before the study began, we met with several villagers and described the series of studies we would be conducting. At this time we also discussed fair compensation. Together, we determined that a participant would be paid the same amount that they would have forfeited by not going to work in the field that day. We set up the equipment in the house of one of the Khmer-Kreung translators. Any adult villager could come to the house if he or she wanted to participate in the study. We did not solicit participation. As most of the villagers in L'ak cannot read or write, we did not obtain written consent. Instead, consent was implied by coming to the house to participate.

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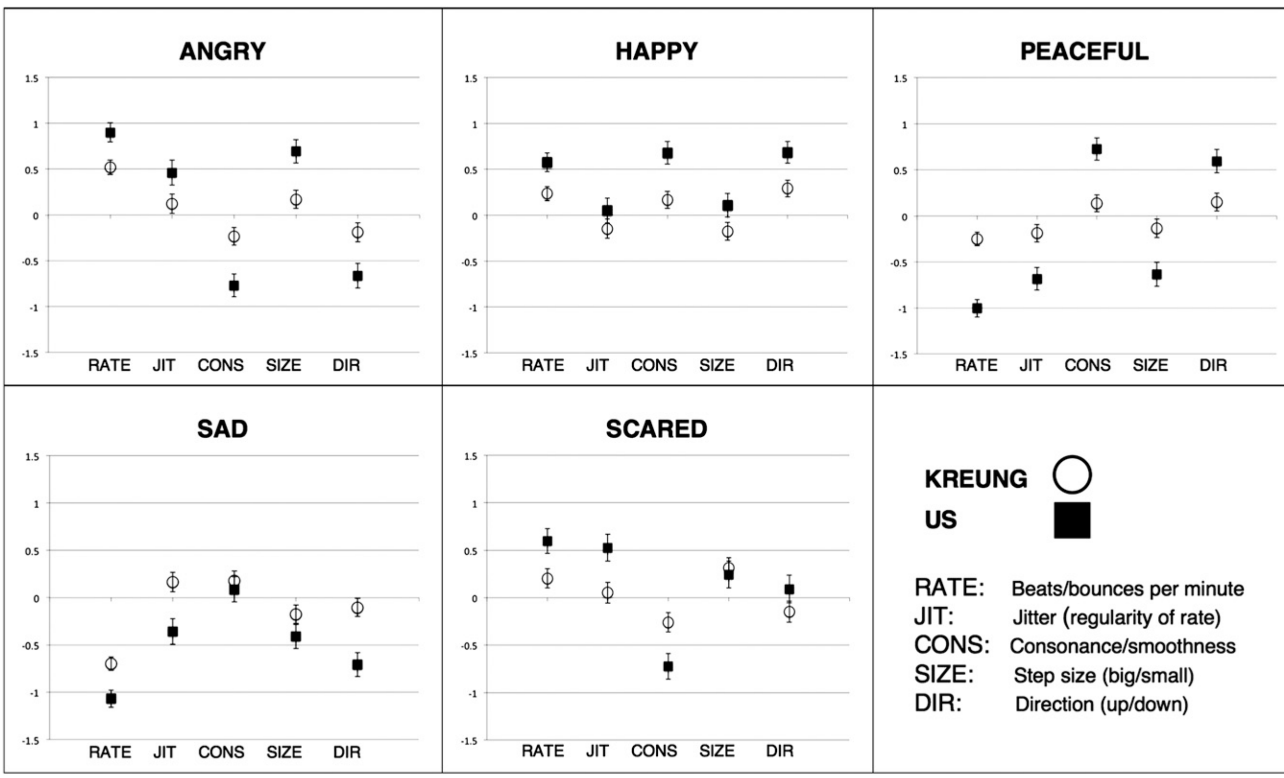


Fig. S1. Average values of *z*-scores (with SE bars) for each slider (i.e., feature) by each emotion and by population. The sign for the up/down slider was flipped for visualization purposes (positive values indicate upward tilt/pitch).

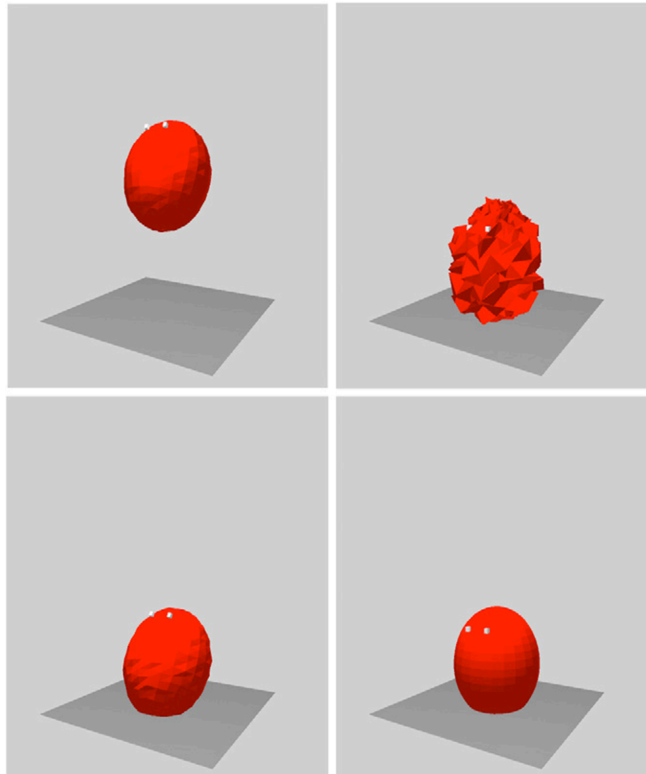
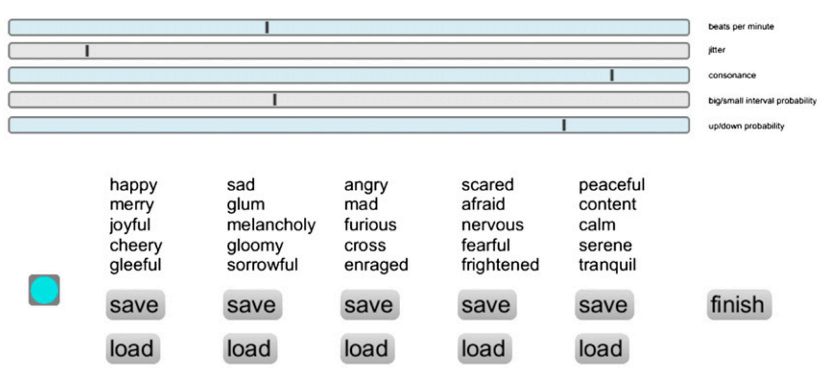


Fig. S2. The Ball.

A. Interface (US)



B. Slider Labels (US)

Music	Movement
Beats per minute	Bounces per minute
Jitter	Jitter
Consonance	Smoothness
Big/small interval probability	Big/small bounce probability
Up/down probability	Lean back/front probability

Fig. S3. (*A*) Interface for the United States music task. (*B*) Slider labels by task modality.

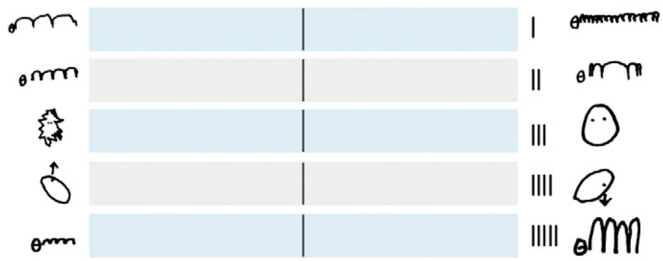


Fig. S4. Interface for the Kreung movement task with icons as a mnemonic aid.

Table S1. Raw means for each slider by emotion for each population

Parameter	Range	Angry	Happy	Peaceful	Sad	Scared
United States means						
Rate	30–400	331.00	280.12	69.48	53.74	289.68
Jitter	0–99	53.70	33.24	11.30	19.44	58.22
Consonance	0–37	8.00	32.00	32.34	22.66	10.08
Size (big/small)	0–100	67.92	49.36	23.66	26.28	52.28
Direction (up/down)	0–100	76.94	35.56	38.34	78.30	51.12
Kreung means						
Rate	0, 1, or 2	1.42	1.18	0.76	0.39	1.15
Jitter	0, 1, or 2	1.06	0.84	0.80	1.09	1.00
Consonance	0, 1, or 2	1.01	1.33	1.31	1.34	0.99
Size (big/small)	0, 1, or 2	1.05	0.75	0.79	0.75	1.16
Direction (up/down)	0, 1, or 2	1.20	0.80	0.92	1.13	1.16

Table S2. *Z*-scored, discrete means for each slider by emotion, for each population

Parameter	Angry	Happy	Peaceful	Sad	Scared
United States discrete means					
Rate	0.90	0.58	−1.00	−1.07	0.60
Jitter	0.46	0.05	−0.68	−0.36	0.53
Consonance	−0.77	0.68	0.72	0.09	−0.72
Size (big/small)	0.69	0.11	0.64	−0.49	0.24
Direction (up/down)	0.66	−0.69	−0.59	0.71	−0.09
Kreung discrete means					
Rate	0.52	0.23	−0.26	−0.70	0.20
Jitter	0.12	−0.15	−0.19	0.16	0.05
Consonance	−0.23	0.17	0.14	0.18	−0.26
Size (big/small)	0.17	−0.17	−0.13	−0.18	0.31
Direction (up/down)	0.19	−0.29	−0.15	0.10	0.15

Table S3. Fisher's linear discriminant analysis

Music and motion	Angry	Happy	Peace	Sad	Scared	Total
Music and Motion						
United States						
Rate	0.02	0.01	0.05	0.07	<0.01	0.16
Jitter	0.01	<0.01	0.02	0.01	0.04	0.09
Consonance	0.58	0.92	0.38	0.18	0.89	2.95
Size (big/small)	0.04	0.01	0.03	0.04	0.01	0.13
Direction (up/down)	0.36	0.06	0.52	0.71	0.06	1.71
Kreung						
Rate	0.67	0.24	0.46	0.82	0.20	2.39
Jitter	0.03	0.05	0.19	0.03	<0.01	0.31
Consonance	0.14	0.17	0.13	0.08	0.32	0.84
Size (big/small)	0.07	0.16	0.10	0.06	0.39	0.78
Direciton (up/down)	0.09	0.39	0.11	<0.01	0.09	0.69
Music						
United States						
Rate	0.04	0.01	0.04	0.12	<0.01	0.22
Jitter	0.02	<0.01	0.07	0.01	0.09	0.20
Consonance	0.27	0.80	0.57	0.55	0.80	2.99
Size (big/small)	0.05	0.02	0.18	0.01	0.07	0.33
Direction (up/down)	0.63	0.16	0.13	0.32	0.03	1.27
Kreung						
Rate	0.30	0.50	0.08	0.95	0.10	1.93
Jitter	0.05	0.04	0.04	<0.01	<0.01	0.15
Consonance	0.46	0.07	0.17	0.03	0.02	0.75
Size (big/small)	0.02	0.14	0.45	0.02	0.66	1.29
Direction (up/down)	0.16	0.26	0.26	<0.01	0.21	0.90
Motion						
United States						
Rate	0.01	<0.01	0.05	0.03	0.01	0.11
Jitter	<0.01	<0.01	0.01	0.02	0.02	0.07
Consonance	0.78	0.91	0.32	0.01	0.75	2.77
Size (big/small)	0.03	0.07	<0.01	0.11	0.11	0.33
Direction (up/down)	0.18	0.01	0.63	0.83	0.12	1.77
Kreung						
Rate	0.89	<0.01	0.65	0.62	0.22	2.39
Jitter	<0.01	<0.01	0.27	0.07	<0.01	0.37
Consonance	0.01	0.20	0.06	0.20	0.73	1.20
Size (big/small)	0.06	0.09	<0.01	0.11	0.04	0.31
Direction (up/down)	0.04	0.70	0.02	0.01	0.01	0.78

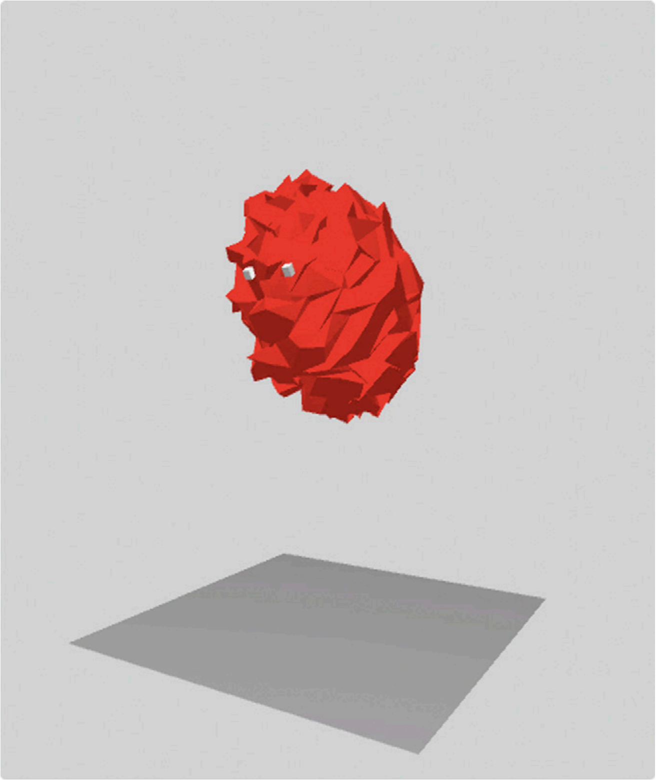
Linear discriminant analysis. Slider importance for discrimination of each emotion from all other emotions. Higher values indicate higher importance.

Table S4. Discretization values for Kreung slider bars (derived from United States data)

Parameter	Low	Medium	High
Rate	55	187	320
Jitter	4	25	61
Consonance	4	30	37
Size (big/small)	15	56	82
Direction (up/down)	39	50	85

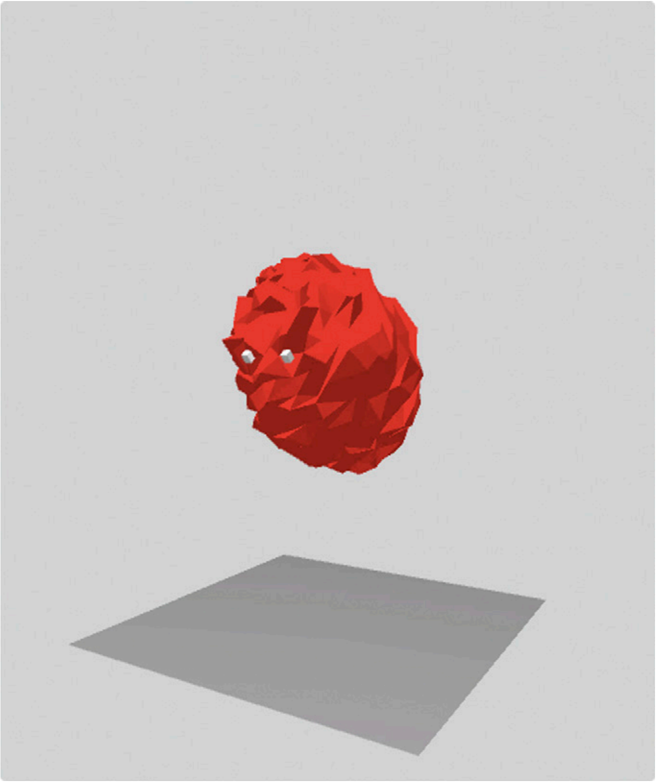
Table S5. χ^2 **Reliability of slider bar use by Kreung participants**

Music and motion	Rate	Jitter	Consonance	Step size (big/small)	Direction (up/down)
Music					
Angry	<0.01	0.49	0.99	0.49	<0.01
Happy	0.10	0.18	<0.01	0.02	0.06
Peaceful	0.03	0.08	<0.01	<0.01	0.65
Sad	<0.01	0.56	<0.01	<0.01	0.34
Sacred	0.08	0.24	0.34	0.04	0.08
Music					
Angry	0.02	<0.01	0.02	0.81	<0.01
Happy	<0.01	0.06	0.01	<0.01	0.06
Peaceful	0.08	0.81	0.17	<0.01	0.61
Sad	<0.01	0.22	0.40	0.15	0.75
Sacred	0.11	0.06	0.42	0.01	0.01
Motion					
Angry	<0.01	0.32	0.02	0.21	0.12
Happy	0.21	0.12	<0.01	0.32	0.12
Peaceful	<0.01	0.03	<0.01	0.10	0.91
Sad	<0.01	0.30	<0.01	0.02	0.42
Sacred	0.21	0.85	0.74	0.85	0.91



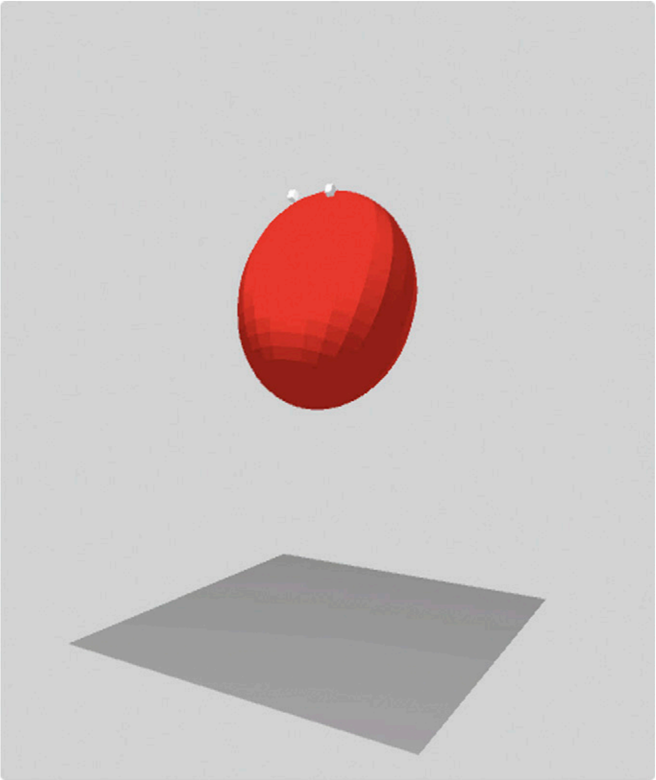
Movie S1. United States angry movement.

Movie S1



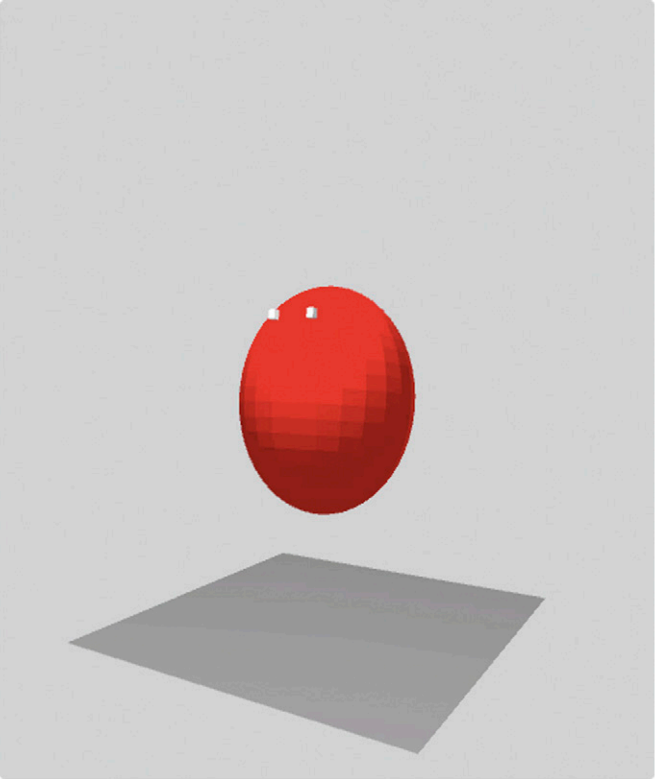
Movie S2. Kreung angry movement.

Movie S2



Movie S3. United States happy movement.

Movie S3

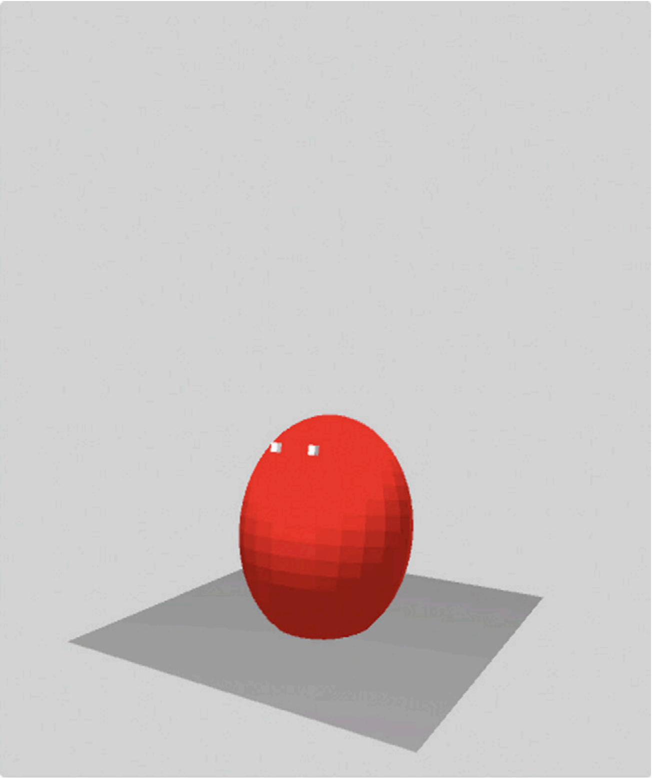


Movie S4. Kreung happy movement.

Movie S4

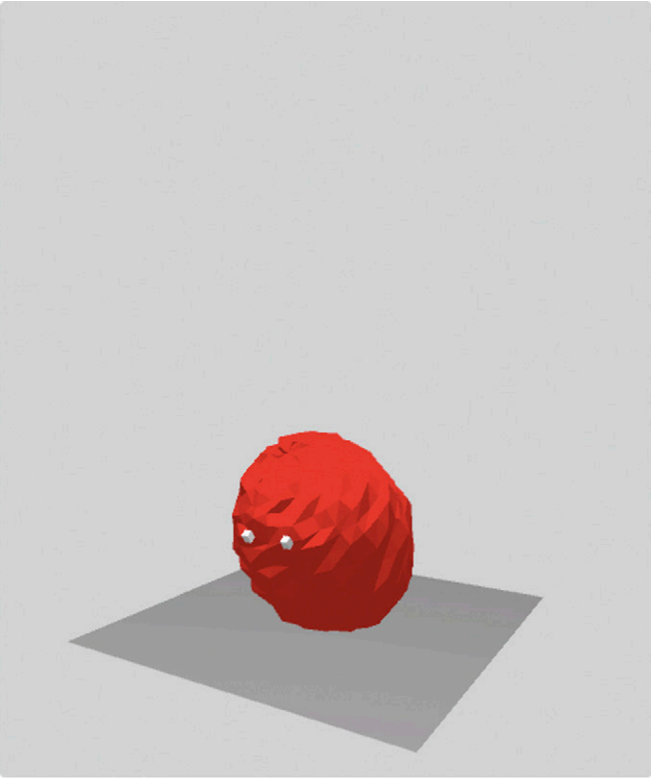
Movie S5. United States peaceful movement.

Movie S5



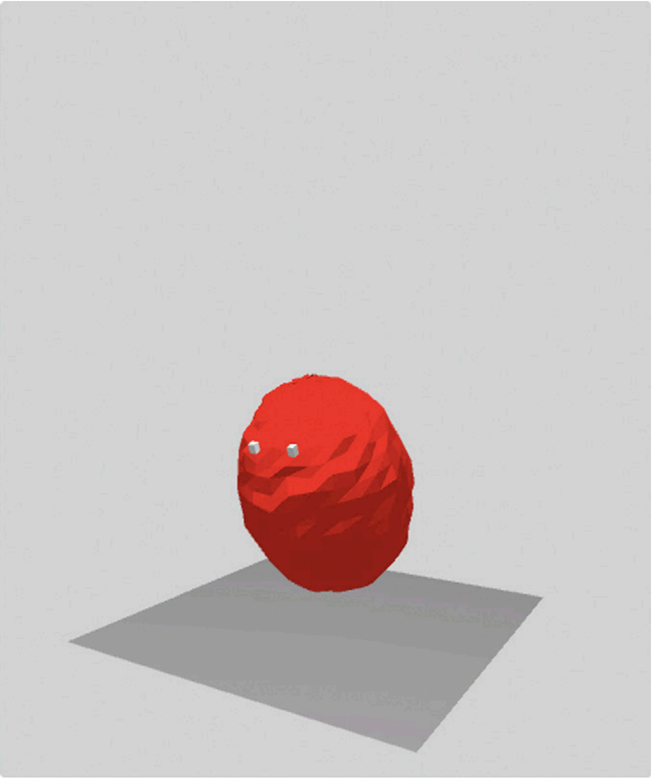
Movie S6. Kreung peaceful movement.

Movie S6



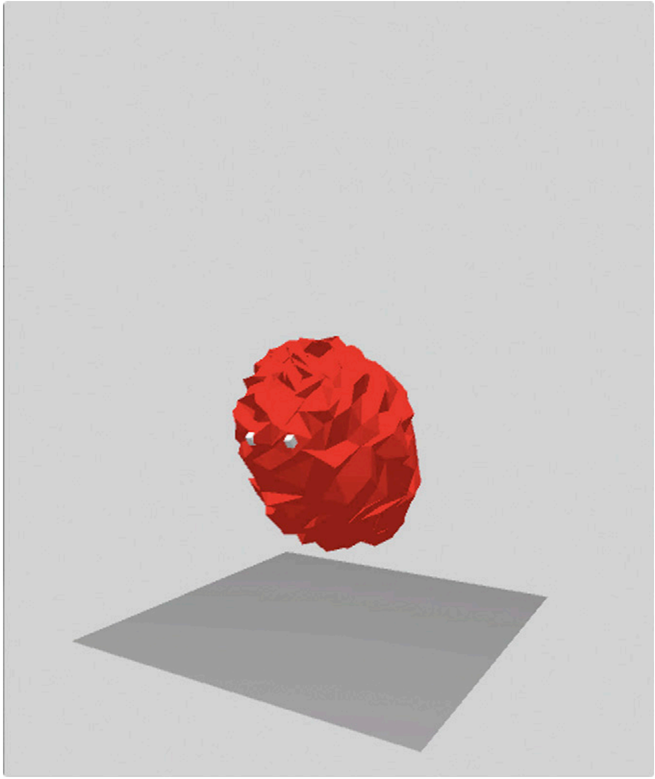
Movie S7. United States sad movement.

Movie S7



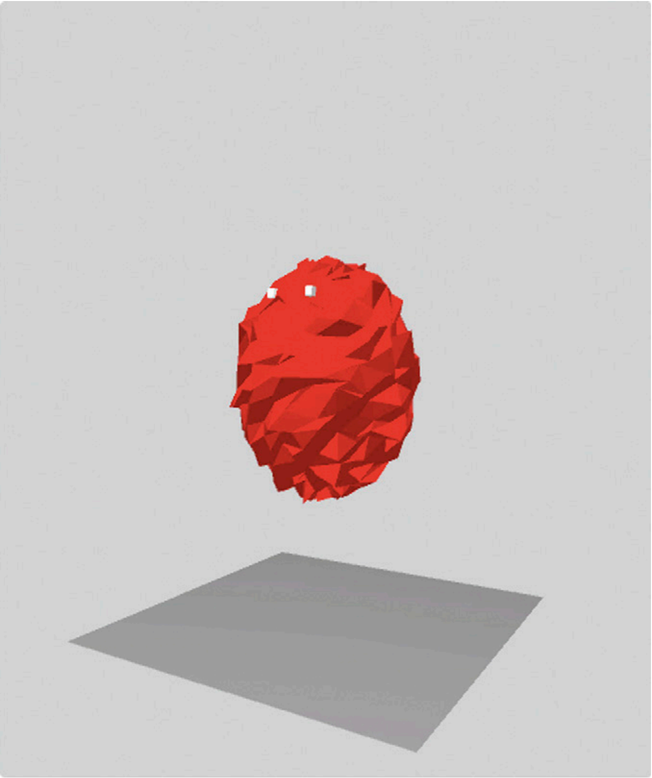
Movie S8. Kreung sad movement.

Movie S8



Movie S9. United States scared movement.

Movie S9



Movie S10. Kreung scared movement.

Movie S10

Audio S1. United States angry music.

Audio S1

Audio S2. Kreung angry music.

Audio S2

Audio S3. United States happy music.

Audio S3

Audio S4. Kreung happy music.

Audio S4

Audio S5. United States peaceful music.

Audio S5

Audio S6. Kreung peaceful music.

Audio S6

Audio S7. United States sad music.

Audio S7

Audio S8. Kreung sad music.

Audio S8

Audio S9. United States scared music.

Audio S9

Audio S10. Kreung scared music.

Audio S10

Audio S11. Example of Kreung gong music, courtesy of Sublime Frequencies.

Audio S11

Audio S12. Example of Kreung *mem* music, Bun Hear, courtesy of Cambodian Living Arts.

Audio S12

Dataset 1. All data from the United States experiment, in continuous format

Dataset S1

Dataset 2. All data from the United States and Kreung experiments

Dataset S2

Kreung data were collected as discrete values (each slider had three positions: 0 1 2). Continuous values from the United States data were converted to discrete values as described in the main text.